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CHAPTER I

INTRODUCTION

There are thousands of plants in the universe, and it is not possible to obtain a satisfactory knowledge of such a diverse multitude of plants without arranging them systematically according to some definite rules or plans.

Systematic Botany is that branch of Botany which deals with such systematic grouping and classification of plants. In its extended sense, the object of Systematic Botany is the naming, describing and arrangement of plants in such a way as to indicate as far as possible their probable line of descent, so that one can at once ascertain their names and at the same time get an insight into their affinities and general properties.

The study of Systematic Botany involves (1) **nomenclature,** *i.e.*, the naming of plants which may or may not indicate any relationship, (2) **taxonomy,*** *i.e.*, the separation and grouping of plants into smaller and higher units on a basis of similarities and differences, which are, as is now believed, the expressions of actual phylogenetic relationship or "blood relationship" as in the case of higher animals, and (3) **classification,** *i.e.*, the arrangement of such units according to some definite plans.

Principles of classification

1. SPECIES. Botanists are almost unanimous in looking upon the species as the unit adopted in formulating the principles of classification, and then building the higher units upon this concept. By the term **species** is understood a collection of individuals, which resemble one another closely in all important characters of vegetative and reproductive organs and are, therefore, supposed to have descended from a common ancestor. If we walk in a rice field we observe thousands of individuals, which, though differing in some respects from one another, are commonly associated under a common name. Such a collection of individuals resembling one another in all important characters constitute what is known as

* H. J. Lam (1948) proposed the term **taxon** "to indicate taxonomic groups of any rank".

a **species,** and this can at once be verified if they breed true from generation to generation, *i.e.*, produce offspring exactly resembling their parents. It should, however, be remembered that such a thing is only possible if the individuals in question are exposed to the influence of the same environmental factors, such as soil, heat, light, moisture, etc., as the parents.

Under certain conditions, however, particularly under changed external conditions, a species may exhibit certain variations in form, size, colour, taste, etc., in the young plants. In this way are produced what are known as **varieties** or **subspecies.** In some cases the variations are only temporary, the individuals reverting to the parent type or perishing altogether. In other cases, however, they are permanent, persisting throughout the life of the individual. But even then, the successive generations of these new individuals will have a tendency to revert to the original specific type from which they have been derived, so that the nature of the plants will depend entirely upon soil characters and other external conditions to which they are exposed. Hence, a variety differs essentially from a species in that it cannot be propagated without tending to revert to the parent type.

Besides the transient varieties referred to above, there are others, which are called **permanent varieties** or **races,** because their characters can be transmitted by seed. The cereal grains, such as wheat, barley, etc., and the vegetables, such as radishes, cabbages and cauliflowers afford good examples. It is impossible to say with certainty how they arose in nature. They, however, present definite or well-marked characters by which they are readily distinguished from the true species.

Another cause which leads to constant variation from the specific type is **hybridization,** a method widely practised by gardeners in raising new forms, which are commonly known as **hybrids** or **cross-breeds.** The hybrid roses and the hybrid mangoes are good examples. But these again are rarely constant and always tend to revert to the original specific type.

Thus, a species must be regarded as a permanent production of nature, which, though varying within certain limits, can never be capable of being modified or altered to such an extent as to resemble a different species. Nothing should be regarded as a new species unless it exhibits some important and distinctive characters in the wild condition.

2. GENERA. As some individuals resemble one another more closely than others, so there are some species which resemble one another more closely than other species. Such allied species are placed under a higher group, called the **genus.** A genus, therefore, is an assemblage of species, which resemble one another in general structure and appearance more than they resemble any other species. Thus, the fig, the banyan, and the India-rubber plant, although constituting different species, present well-marked resemblances to one another in certain characters, and are, therefore, placed under one common genus, viz., *Ficus*. The characters of a genus are derived exclusively from the reproductive organs, while those of the species are generally taken from all parts of the plant body. A genus, therefore, may be strictly defined as a collection of species, which bear similarity to one another in the general characters of their organs of reproduction. A genus does not necessarily contain a number of species. A single species on account of its presenting certain well-marked peculiarities may itself constitute a genus. Such genera are known as **monotypic** ones.

3. FAMILIES. If we follow this principle of classification, we find that some genera are more allied to one another than to other genera. Such allied genera are grouped together into a still higher grade, called the **family.** Thus, the thorn apples, potatoes and chillies, although belonging to different genera, present certain well-defined resemblances to one another, and are, therefore, included in the family Solanaceae. Again, the roses, apples and plums all belong to different genera but to one family, viz., Rosaceae.

It is, however, often found that there are certain genera, which more closely resemble one another than they do other genera of the same family. Thus, the pulses, indigo, tamarind, *Acacia*, and the sensitive plant all belong to the same family, but the *Acacia* and the sensitive plant show more resemblances to each other than do the tamarind and the indigo. Hence, while all of them belong to the same family Leguminosae, they are at the same time placed under three different **subfamilies.** Thus, the indigo and pulses belong to the subfamily Papilionaceae, the tamarind to the subfamily Caesalpinieae, and the *Acacia* as well as the sensitive plant to the subfamily Mimosae.

Following the same principle of resemblances and differences, the families are grouped into **Orders,** orders into **Subclasses,** sub-

classes into **Classes,** classes into **Divisions** till we arrive at the whole collection of plants known as the **Vegetable Kingdom.**

Nomenclature

The art of naming and describing a plant accurately is one of the main objects of Systematic Botany. This involves the use of certain technical terms, so that it may be readily recognized by one, who has a knowledge of these terms but to whom the plant was previously unknown. Every species of a plant has a name by which it is distinguished from any other species. Thus, the thorn apple is named *Datura fastuosa*, the custard apple as *Anona squamosa*, and the apple as *Pyrus malus*. The name of each plant thus consists of two parts ; the first part indicates the genus to which the plant belongs and is always placed before the second part, which indicates its species. It is thus seen that the three plants mentioned above not only belong to different species but also to different genera. The first part of each name is called the **generic** name and the second, the **specific** one. Two or more species belonging to the same genus have, of course, the same generic name. Thus, the custard apple and the bullock's heart both belong to the same genus *Anona*, but to two different species, viz., *squamosa* and *reticulata* respectively.

This system of naming plants is called the **binomial nomenclature.** It is customary to put the name of the author in an abbreviated form after the specific name of the plant* in order to denote the name of the person, who described the plant for the first time, or to avoid confusion which may arise from the description of the same plant published by a different author from a different part of the globe. For example, the common mango is termed *Mangifera indica* Linn. after the well-known botanist Linnaeus.

Specific names are derived from various sources. Sometimes they are derived from the name of the country to which a plant originally belonged, for example, *Argemone mexicana* means that the native home of the plant is Mexico, *Ficus indica* means that the plant is indigeneous to India, etc. Sometimes they refer to the habit of a plant, such as *Mentha arvensis*, which is found in fields; or they may express some obvious morphological character of the species,

* Both the generic and specific names are, as a rule, indicated in italics, while the author's name is printed in Roman script, e.g., *Polyalthia longifolia* Benth. & Hook. (the common devdaru).

such as *Butomopsis lanceolata*, with lanceolate leaves, *Ruellia tuberosa*, with tuberous roots, *Viola tricolor* with tricoloured flowers, and so on.

The generic names may also be variously derived. They may refer to the names of some eminent botanists, such as *Jussiaea* after Jussiaeu, *Caesalpinia* after Caesalpinus, or to some peculiarity of structure, or habit, or to various other sources. Thus, *Sagittaria* is derived from its arrow-shaped leaves, *Campanula* from its bell-shaped corolla, *Lactuca* from its milky juice, etc.

On similar principles the names of families are also derived in various ways. They are usually taken from some well-known genus. Thus, the genus *Malva* gives the name Malvaceae to the family to which it belongs. Likewise, the genera *Lilium*, *Orchis*, *Cyperus*, *Asclepias*, *Convolvulus*, *Amarantus*, etc., give name respectively to the families Liliaceae, Orchidaceae, Cyperaceae, Asclepiadaceae, Convolvulaceae, Amaranthaceae, and so on. At other times, however, they are derived from some characteristic feature of the plants included in them. Thus, the name Cruciferae is derived from flowers having cruciform corolla, Umbelliferae, from the umbel inflorescence, Leguminosae, from the fruit which is a legume, etc.

The names of the Classes, Divisions, etc., are derived from some permanent characters of the plants placed in them and refer either to the structure or mode of development. Familiar examples are the Dicotyledons and the Monocotyledons meaning that the former have two cotyledons and the latter only one.

History of Taxonomy

Taxonomy, in its wide sense, includes the study of the various types of plants, their identification, their characteristics, habitats and distribution as well as their affinities. Thus, it helps in a scientific reconstruction of the entire plant kingdom. With this end in view, various attempts have been made from the times of the earliest Indian and Greek savants like **Charak, Sushrut, Plato, Aristotle, Pliny,** and **Dioscorides.** These sages were, however, concerned more with philosophy than with nature. **Theophrastus** (370-285 B.C.), a disciple of Aristotle, is regarded as the father of Botany. Though he made an attempt to a more intelligent approach to the groupings of plants, yet he could not tide over the influence of philosophy of his teacher.

The aim and object of Systematic Botany, as already stated,

is, apart from naming and describing the plants, to arrange them in such a way as to indicate as far as possible their probable line of descent. The numerous **systems** that have been devised for this purpose do not, however, conform to this view. For, while some systems readily enable us to ascertain their names, others not only fulfil it, but at the same time give us an idea as to their relationships. Based on this, the different systems have been broadly divided under two heads, namely, **artificial** and **natural,** the former enabling us to ascertain the names only, while the latter fulfil all the conditions, which come within the scope of Systematic Botany. The artificial system places together in a group those plants that resemble one another mainly in *one* prominent character (*i.e.*, sex character), while the natural system places together in a group those plants that *resemble one another in a number of prominent characters indicating a close relationship amongst them.* Furthermore, in the artificial systems closely allied plants are widely separated and placed in different groups, because of the absence of one particular character, while plants, which have no relation to one another, are brought together under the same group, because of the presence of that character alone.

The ultimate object of Systematic Botany should be the development of a natural system, which would aim to arrange plants in such a way as to give us an idea of the sequence of evolution in the Plant Kingdom. It should naturally start with forms which are simple and are, therefore, regarded as primitive, and gradually advance to higher and more complex forms till the highest group of plants is attained. Such a system is called **phylogenetic.** The systematist tries to make his system phylogenetically true as far as possible. A perfectly phylogenetic system is, therefore, an ideal system, but so far it is far from being achieved. The reason of this lies in the fact that the assumptions on which such a system is to be based are theoritical, and the data that have so far been available are very imperfect. But this can only be remedied as our knowledge of plants inhabiting the different parts of the globe becomes more and more extended.

The credit of the present-day form of Systematic Botany must go to the herbalists of the sixteenth and seventeenth centuries, like **Otto Brunfels** (1464-1534), **Jerome Bock** (1498-1554), **Leonhard Fuchs** (1501-1566), **Mattias de L'Obel** (1538-1616), **John Gerard** (1545-1612), and **Charles L'Ecluse** (1526-1609).

Andrea Cesalpino (1519-1603) is usually regarded as the first plant taxonomist. He classified plants firstly on the basis of habit,

Fig. 1. Andrea Cesalpino.

Fig. 2. Gaspard Bauhin.

and secondarily on the characters of fruits and seeds. In this connection of the systems of classification based on the habits of plants, mentions must be made of the names of **Jean** (**Johna**) **Bauhin** (1541-1631), **Joseph Pitton de Tournefort** (1656-1708), the father of the modern concept of genera, and **Gaspard** (**Casper** or **Kaspar**) **Bauhin** (1560-1624), brother of Jean Bauhin. It is of interest to note that in the works of Gaspard Bauhin the plants were freque-ntly referred to with a binary nomenclature, thus distinguishing between genera and species.

Fig. 3. John Ray.

John Ray (1628-1705), an English philosopher and natura-list, propounded a system of plant

classification. In this system he gave much importance to the habits of plants no doubt, yet laid the first foundation of the natural system. In his *Historia plantarum* (1686-1704), Ray classified about 18,000 species of plants under two major divisions, namely, **Herbae** (herbs) and **Arbores** (trees). He subdivided the Herbae into **Imperfectae** and **Perfectae.** The Perfectae and the Arbores were further divided into **Dicotyledones** and **Monocotyledones.** Ray was the first to recognize positively the two taxa of monocotyledonous and dicotyledonous plants, basing on the presence of either one or two cotyledons in the embryo.

Fig. 4. Carolus Linnaeus.

About thirty years later **Carolus Linnaeus** or **Carl Linne** (1707-1778), a Swedish naturalist, regarded as the father of taxonomy, brought out his system known as the **Sexual system** in his *Systema Naturae* (1735).

The Classes and Orders in this system are based exclusively upon the sporophylls (stamens and carpels of higher plants), which were considered to be the sexual organs of the plant. Hence, the Linnaean system is also known as the **Sexual system.** Linnaeus divided plants primarily into 24 Classes, (one of which is *Cryptogamia*), according to the number, nature and distribution of their stamens. Thus, plants with one stamen are placed in the Class *Monandria*, those with two stamens in the Class *Diandria*, those with three in the Class *Triandria*, and so on. The Classes were again subdivided into smaller groups or Orders, according to the number and condition of their carpels, styles or stigmas, or according to the number and condition of stamens which have not been used as the basis of classes, or according to the nature of flowers or fruits. Thus, plants with one carpel were placed in the Order *Monogynia*, those with two carpels in the Order *Digynia*, those with three in the Order *Trigynia*, and so on.

A detailed scheme of the Linnaean system of classification is given below :

Classes	*Orders*
I. **Monandria** (stamen one)	Monogynia
II. **Diandria** (stamens two)	Monogynia Trigynia
III. **Triandria** (stamens three)	Monogynia Digynia Trigynia
IV. **Tetrandria** (stamens four)	Monogynia Digynia Tetragynia
V. **Pentandria** (stamens five)	Monogynia Digynia Trigynia Pentagynia
VI. **Hexandria** (stamens six)	Monogynia Digynia Trigynia Hexagynia
VII. **Heptandria** (stamens seven)	Monogynia
VIII. **Octandria** (stamens eight)	Monogynia Trigynia Tetragynia
IX. **Enneandria** (stamens nine)	Monogynia Hexagynia
X. **Decandria** (stamens ten)	Monogynia Digynia Trigynia Pentagynia Polygynia
XI. **Dodecandria** (stamens twelve)	Monogynia Trigynia
XII. **Icosandria** (stamens more than twelve, attached to the calyx)	Monogynia Digynia Pentagynia Polygynia
XIII. **Polyandria** (stamens more than twelve, attached to the receptacle)	Monogynia Tetragynia Pentagynia Polygynia

Classes	*Orders*
XIV. **Didynamia** (stamens didynamous) ..	Gymnospermia Angiospermia
XV. **Tetradynamia** (stamens tetradynamous)	Siliculosa Siliquosa
XVI. **Monadelphia** (stamens in one bundle)	Pentandria Hexandria Decandria Dodecandria Polyandria
XVII. **Diadelphia** (stamens in two bundles)	Triandria Hexandria Octandria Decandria
XVIII. **Polyadelphia** (stamens in several bundles)	Icosandria Polyandria
XIX. **Syngenesia** (stamens with united anthers)	Aequalis Superflua Frustranea Segregata
XX. **Gynandria** (stamens adnate to the pistils)	Monandria Hexandria
XXI. **Monoecia** (plants monoecious) ..	Monandria Diandria Triandria Tetrandria Pentandria Hexandria Polyandria Monadelphia Syngenesia Gynandria
XXII. **Dioecia** (plants dioecious) ..	Monandria Diandria Triandria Tetrandria Pentandria Hexandria Enneandria Decandria Icosandria Polyandria Monadelphia

Classes	*Orders*
XXIII. **Polygamia** (plants polygamous) ..	Monoecia Dioecia Trioecia
XXIV. **Cryptogamia** (flowers concealed) ..	Miscellanea Filices

The special merit of the Linnaean system lies in the fact that it is an excellent example of the limitation of the artificial system. Here we depend for the groupings on characters derived from one set of organs instead of considering the aggregate of characters as we should do in a natural system. It is just like a dictionary where the words arranged alphabetically have no relationship to one another, or like a library where the books are placed side by side purely depending upon the subject matter, so that any word in the dictionary or any book in the library can be readily referred to. It is to Linnaeus that we owe the foundation of a true binomial system of nomenclature, though many plants had been known by a binomial title long before Linnaeus' time. Linnaeus made binomial nomenclature a fixed rule, and his careful study of the whole plant world and the indication and definition of genera and species were perhaps the most important contributions ever made to Systematic Botany.

The system of Linnaeus gained a wider circulation due to the efforts of some of his students like **Pehr** (**Peter**) **Kalm** (1716-1779), **Fredrick Hosselquist** (1722-1752), and **Carl Peter Thunberg** (1743-1828).

It was actually in France that the first seed for a natural system of classification was sown. **Bernard de Jussieu** (1699-1776), Professor and Demonstrator of Botany at the Royal Garden of La Trianon, Versailles, modified the system of Linnaeus to a great extent, but never published his work. Later on, his nephew **Antoine Laurent de Jussieu**(1748-1836) made some improvement over his uncle's system and published the same in his *Genera Plantarum secundum Ordines naturales disposita*. The Orders or Families (which he termed as 'Ordines naturales') in his system numbered one hundred, all of which are practically still recognized. They were arranged in fifteen Classes, of which Class I was termed the **Acotyledones,** which contained algae, fungi, hepaticae, musci, filices and an Order Naiades including large number of aquatic flowering plants having

no affinities. Classes II, III and IV belonged to the **Monocotyledones,** while the rest were all included under the **Dicotyledones.** In his system Jussieu adopted the distinction between Monocotyledones and Dicotyledones, as suggested by Ray, but at the same time regarded the Acotyledones (equivalent to the present-day Cryptogams) as a Class of the same status or rank with either of the Classes of seed plants.

Fig. 5. Antoine de Jussieu.

Another great pioneer in the field of the system of plant classification was **Augustus Pyrame de Candolle** (1778-1841). While working as the Professor of Botany at Montpellier, he published his epoch-making book *Theorie elementaire de la botanique* in 1813, in which he suggested that morphology of plants and not their physiology must be considered as the primary basis of classification. It is, however, a very interesting as well as strange fact that in presenting his system he selected an anatomical character, namely the presence or absence of vessels (which were, according to him, organs of prime importance in nutrition). On the basis of this, he classified plants broadly into two main groups, **Vascular plants** or plants with cotyledons and **Cellular plants** or plants without cotyledons. The former group was again divided into **Exogens** or Dicotyledons and **Endogens** or Monocotyledons, which differed not only in the number of cotyledon or cotyledons in the embryo, but also were supposed to differ in the mode of growth in thickness.

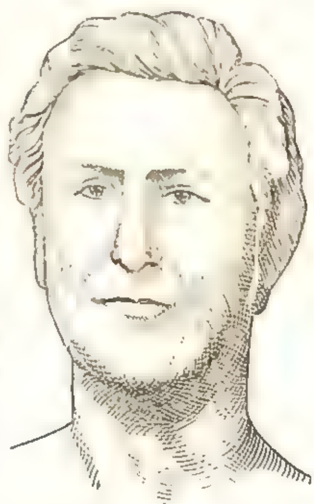

Fig. 6. A. P. de Candolle.

Robert Brown (1773-1858), an English botanist, published his work entitled *Botanicorum facile princeps*, wherein he did not suggest any new system of classification but classified some intricate and difficult points of floral morphology as well as problems on the unknown or doubtful affinities of some families.

Fig. 7. Robert Brown.

During the period of twenty years extending from 1825-1845 about two dozens of different systems of plant classification were proposed by various workers like **Brongniart** (1770-1847), **John Lindley** (1799-1865) and **Endlicher** (1805-1849).

Almost all the systems of classification up to 1850 were mainly concerned with the asexual plants (Cryptogams). This was rather an unsatisfactory state of affairs. It was **Hofmeister,** who in 1851 explained clearly the phenomenon of alternation of generations, and thus the relationships of the flowerless plants amongest themselves as well as to the flowering plants were brought into light. Hofmeister's theory, in fact, suggested the key to the establishment of a natural system.

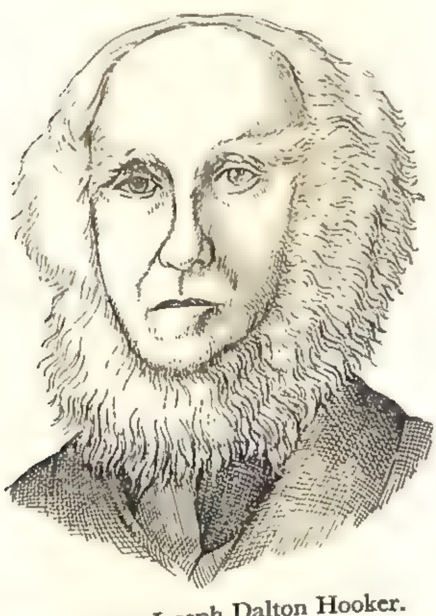

Fig. 8. Sir Joseph Dalton Hooker.

Of all the natural systems announced so far, Bentham and Hooker's system had gained the maximum popularity. **George Bentham** (1800-1884) and **Joseph Dalton Hooker** (1817-1911), two Englishmen, jointly produced the monumentous

work *Genera plantarum* (1862-1883) in which all the genera of seed plants, known up to that time, were described and classified according to a definite system. It is of interest to note that the pattern of the system of Bentham and Hooker is based mainly on that of de Candolle.

Bentham and Hooker divided plants into two great **Subkingdoms**—*Cryptogamia* and *Phanerogamia*. The latter subkingdom was divided into two **Divisions**—*Gymnospermia* and *Angiospermia*. The Angiospermia were divided into two **Classes**—*Dicotyledones* and *Monocotyledones*. The Dicotyledones were divided into three **Subclasses**—*Polypetalae*, *Gamopetalae* and *Monochlamydeae*. Polypetalae were divided into three **Series**—*Thalamiflorae*, *Disciflorae* and *Calyciflorae*, and the Gamopetalae into three Series—*Inferae*, *Heteromerae* and *Bicarpellatae*. The Monochlamydeae were divided into eight Series, and the Monocotyledones into seven Series. The Series were next divided into **Cohorts,** Cohorts into **Orders,** Orders into **Genera,** and finally each Genus into **Species.** The *Gymnospermia* were placed in between Dicotyledones and Monocotyledones. There are altogether 202 Orders, the Dicotyledones beginning with *Ranunculaceae* and ending in *Labiatae*, while the Monocotyledones beginning with *Hydrocharideae* and ending in *Gramineae*.

Subkingdom I. Cryptogamia (*kryptos* = hidden; *gamos* = marriage) or "flowerless plants", are those plants which have no evident flowers with stamens or pistils, and reproduce by spores or spore-like bodies which are usually unicellular and never contain anything like an embryo The Cryptogamia have been divided into Thallophyta, Bryophyta and Pteridophyta.

Subkingdom II. Phanerogamia (*phaneros* = evident; *gamos* = marriage) or "flowering plants", are those plants which produce evident flowers with stamens or pistils or both, and usually with a perianth. They usually reproduce by seeds which are complex multicellular bodies and always contain an embryo. Hence, they are also known as "seed-plants" or **Spermatophytes.**

Division 1. Gymnospermia (*gymnos* = naked; *sperma* = a seed) or "naked-seeded" plants, are those plants in which the carpellary leaves do not unite to form an ovary and the seeds are, therefore, exposed. The pollen grains fall directly upon the micropyle of the ovule. True vessels and perianth are absent (except in Gnetales).

Division 2. Angiospermia (*angeion* = a vessel; *sperma* = a seed) or "closed-seeded" plants, are those in which the carpellary leaves unite by their margins to form an ovary with styles and stigmas, so that the seeds lie within a chamber. Pollen grains fall directly on the stigma. True vessels are present. They include the largest majority of existing flowering plants.

Class I. *Dicotyledones*—These plants bear two cotyledons in their embryo; the radicle on germination produces a tap-root; leaves with reticulate venation; flowers usually pentamerous. Vascular bundles of the stem open and arranged in a ring and those of the root di-, tri- or tetra-arch.

Class II. *Monocotyledones*—These plants bear only one cotyledon in their embryo; the radicle on germination produces a number of adventitious roots; leaves with parallel venation and sheathing bases; flowers usually trimerous. Vascular bundles of the stem closed and scattered irregularly and those of root polyarch.

A tabular classification of the Dicotyledones and the Monocotyledones is given below.

DICOTYLEDONES

SUBCLASS. I. POLYEPETALAE

Series i. THALAMIFLORAE. Petals and stamens hypogynous.

Cohort 1. *Ranales.* Orders: *1, Ranunculaceae; 2, Dilleniaceae; 3, Calycanthaceae; *4, Magnoliaceae; *5, Anonaceae; 6, Menispermaceae; 7, Berberideae; *8, Nymphaeaceae.

" 2. *Parietales.* Orders: 9, Sarraceniaceae; *10, Papaveraceae; *11, Cruciferae; *12, Capparideae; 13, Resedaceae; 14, Cistineae; 15, Violarieae; 16, Canellaceae; 17, Bixineae.

" 3. *Polygalineae.* Orders: 18, Pittosporeae; 19, Tremandreae; 20, Polygaleae; 21, Vochysiaceae.

" 4. *Caryophyllinae.* Orders: 22, Frankeniaceae; *23, Caryophylleae; *24, Portulacaceae; 25, Tamariscineae.

" 5. *Guttiferales.* Orders: 26, Elatineae; 27, Hypericineae; *28, Guttiferae; 29, Ternstroemiaceae; *30, Dipterocarpeae; 31, Chlaenaceae.

" 6. *Malvales.* Orders: *32, Malvaceae; *33, Sterculiaceae; *34, Tiliaceae.

Series ii. DISCIFLORAE. Stamens usually definite, inserted upon or inside or outside of a development of the floral axis which forms a ring or cushion at the base of the ovary, or is broken up into glands. Ovary superior.

Cohort 7. *Geraniales.* Orders: 35, Lineae; 36, Humiriaceae; 37, Malpighiaceae; 38, Zygophylleae; *39, Geraniaceae; *40, Rutaceae;

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*Orders marked with an asterisk are treated in this book.

41, Simarubeae; 42, Ochnaceae; 43, Burseraceae; *44, Meliaceae; 45, Chailletiaceae.

Cohort 8. *Olacales.* Orders: 46, Olacineae; 47, Ilicineae; 48, Cyrilleae.

„ 9. *Celastrales.* Orders: 49, Celastrineae; 50, Stackhousieae; *51, Rhamneae; *52, Ampelideae.

„ 10. *Sapindales.* Orders: *53, Sapindaceae; 54, Sabiaceae; *55, Anacardiaceae.

Ordines anomali: 56, Coriarieae; 57, Moringeae.

Series iii. Calyciflorae. Petals and stamens perigynous. Ovary often more or less enclosed by the development of the floral axis, sometimes inferior.

Cohort 11. *Rosales.* Orders: 58, Connaraceae; *59, Leguminosae; *60, Rosaceae; 61, Saxifrageae; *62, Crassulaceae; 63, Droseraceae; 64, Hamamelideae; 65, Bruniaceae; 66, Halorageae.

„ 12. *Myrtales.* Orders: *67, Rhizophoreae; *68, Combretaceae; *69, Myrtaceae; *70, Melastomaceae; *71, Lythraceae; *72, Onagraceae.

„ 13. *Passiflorales.* Orders: 73, Samydaceae; 74, Loaseae; 75, Turneraceae: *76, Passifloreae; *77, Cucurbitaceae; 78, Begoniaceae; 79, Datisceae.

„ 14. *Ficoidales.* Orders: *80, Cacteae; 81, Ficoideae.

Cohort 15. *Umbellales.* Orders: *82, Umbelliferae; 83, Araliaceae; 84, Cornaceae.

SUBCLASS 2. GAMOPETALAE

Series i. Inferae. Ovary inferior. Stamens as many as the corolla-lobes, rarely fewer.

Cohort 1. *Rubiales.* Orders: 85, Caprifoliaceae; *86, Rubiaceae.

„ 2. *Asterales.* Orders: 87, Valerianeae; 88, Dipsaceae; 89, Calycereae; *90, Compositae.

„ 3. *Campanales.* Orders: 91, Stylideae; 92, Goodenoviae; 93, Campanulaceae.

Series ii. Heteromerae. Ovary generally superior. Stamens as many as the corolla-lobes, or more; epipetalous or free from the corolla. Carpels more than two.

Cohort 4. *Ericales.* Orders: 94, Ericaceae; 95, Vaccinieae; 96, Monotropeae; 97, Epacrideae; 98, Diapensiaceae; 99, Lennoaceae.

„ 5. *Primulales.* Orders: 100, Plumbagineae; 101, Primulaceae; 102, Myrsineae.

„ 6. *Ebenales.* Orders: *103, Sapotaceae; 104, Ebenaceae; 105, Styraceae.

Series iii. Bicarpellatae. Ovary generally superior. Stamens alternate with the corolla-lobes and equal in number or fewer. Carpels usually two.

Cohort 7. *Gentianales.* Orders: *106, Oleaceae; 107, Salvadoraceae; *108, Apocynaceae; *109, Asclepiadaceae; 110, Loganiaceae; *111, Gentianaceae.

Cohort 8. *Polemoniales*. Orders: 112, Polemoniaceae; 113, Hydrophyllaceae; *114, Boragineae; *115, Convolvulaceae; *116, Solanaceae.

„ 9. *Personales*. Orders: *117, Scrophularineae; 118, Orobanchaceae; *119, Lentibulariaceae; 120, Columelliaceae; 121, Gesneraceae; *122, Bignoniaceae; *123, Pedalineae; *124, Acanthaceae.

„ 10. *Lamiales*. Orders: 125, Myoporineae; 126, Selagineae; *127, Verbenaceae; *128, Labiatae.

Ordo amomalus: 129, Plantagineae.

SUBCLASS 3. MONOCHLAMYDEAE

Series i. CURVEMBRYEAE. Embryo curved round the generally mealy albumen. Ovules generally solitary. Flowers usually hermaphrodite. Stamens equal in number to or fewer than the perianth segments. Orders: *130, Nyctagineae; 131, Illecebraceae; *132, Amarantaceae; *133, Chenopodiaceae; 134, Phytolacaceae; 135, Batideae; *136, Polygonaceae.

Series ii. MULTIOVULATAE AQUATICAE. Submerged herbs. Ovary syncarpous. Ovules numerous.
Order: 137, Podostemaceae.

Series iii. MULTIOVULATAE TERRESTRES. Terrestrial herbs or shrubs. Ovary syncarpous. Ovules numerous.
Orders: 138, Nepenthaceae; 139, Cytinaceae; 140, Aristolochiaceae.

Series iv. MICREMBRYEAE. Embryo very small in a copious albumen. Ovary syncarpous or apocarpous. Ovules usually solitary.
Orders: *141, Piperaceae; 142, Chloranthaceae; 143, Myristicaceae; 144, Monimiaceae.

Series v. DAPHNALES. Ovary usually monocarpellary. Ovules solitary or in pairs. Generally trees or shrubs with hermaphrodite flowers. Perianth sepaloid in one or two series.
Orders: *145, Laurineae; 146, Proteaceae; 147, Thymeleaceae; 148, Penaceae; 149, Elaeagnaceae.

Series vi. ACHLAMYDOSPOREAE. Ovary unilocular; 1-3- ovuled, Seeds devoid of testa. Albumen naked. Perianth sepaloid or petaloid.
Orders: *150, Loranthaceae; *151, Santalaceae; 152, Balanophoreae.

Series vii. UNISEXUALES. Flowers unisexual. Ovary syncarpous or monocarpellary. Ovules solitary or in pairs. Seeds albuminous or exalbuminous. Perianth sometimes absent.
Orders: *153, Euphorbiaceae; 154, Balanopseae; *155, Urticaceae; 156, Platanaceae; 157, Leitneriace; 158, Juglandeae; 159, Myricaceae; *160, Casuarineae; 161, Cupuliferae.

Series viii. ORDINES ANOMALI. Near the last Series but not closely allied to any other Order. Flowers often unisexual.
Orders: *162, Salicineae; 163, Lacistemaceae; 164, Empetraceae; 165, Ceratophylleae.

GYMNOSPERMAE

Orders: *166 Gnetaceae; *167, Coniferae; *168, Cycadaceae.

MONOCOTYLEDONES

Series i. MICROSPERMAE. At least the inner perianth petaloid. Ovary inferior, generally unilocular with three parietal placentae. Seeds very small, numerous and exalbuminous.
Orders: *169, Hydrocharideae; 170, Burmanniaceae; *171, Orchidaceae.

Series ii. EPIGYNAE. At least the inner perianth petaloid. Ovary with a few exceptions inferior. Albumen copious.
Orders: *172, Scitamineae; 173, Bromeliaceae; 174, Haemodraceae; 175, Irideae; *176, Amaryllideae; 177, Taccaceae; 178, Dioscoreaceae.

Series iii. CORONARIEAE. At least the inner perianth petaloid. Ovary free. Albumen copious.
Orders : 179, Roxburghiaceae; *180, Liliaceae; *181, Pontederiaceae; 182, Philydraceae; 183, Xyrideae; 184, Mayaceae; *185, Commelinaceae; 186, Rapataceae.

Series iv. CALYCINAE. Perianth small, sepaloid, somewhat stiff or herbaceous. Ovary free. Albumen copious.
Orders: 187, Flagellarieae; 188, Juncaceae; *189, Palmae.

Series v. NUDIFLORAE. Perianth 0 or reduced to scales or setae. Ovary superior, carpels solitary or, if many, syncarpous, 1—many-ovuled. Seeds usually albuminous.
Orders: *190, Pandaneae; 191, Cyclanthaceae; *192, Typhaceae; *193, Aroideae; *194, Lemnaceae.

Series vi. APOCARPEAE. Perianth in 1 or 2 series or 0. Ovary superior. Carpels solitary or free. Seeds exalbuminous.
Orders: 195, Triurideae; *196, Alismaceae; 197, Naiadaceae.

Series vii. GLUMACEAE. Flowers in heads or spikelets, subtended by generally imbricated bracts. Perianth small, scale-like, or glumaceous, or 0. Ovary 1-ovuled or divided into 1-ovuled loculi. Seeds albuminous.
Orders: 198, Eriocauleae; 199, Centrolepideae; 200, Restiaceae; *201, Cyperaceae; *200, Gramineae.

Merits and Demerits

Merits:

1. It is a great natural system, perhaps the first of its kind.
2. It is very suitable for all practical purposes.
3. Beginning of Polypetalae with Ranales, composed of the well-known Ranunculaceae and its allies.
4. Monocotyledons are derived from Dicotyledons.

Demerits:

1. The classification is based mainly on single and mostly artificial characters. Hence, closely related orders are often widely separated.

2. It is not phylogenetic.
3. Monochlamydeae are grouped apart from Polypetalae.
4. Some Orders with simple flowers have close relationship with some Orders with well-developed floral configuration, hence, they should be placed nearer in a natural system of classification. For example, Chenopodiaceae should be brought nearer to Caryophyllaceae.
5. In the classification of Monocotyledons, Scitamineae and Orchidaceae are placed at the very beginning, but these cannot be regarded as primitive with so many advanced characters.
6. In the subdivision of Monocotyledons, stress has been laid on the relative position of ovary and the character of the perianth. Thus, Irideae and Amaryllideae are more nearly related to Liliaceae than to Scitamineae or Bromeliaceae with which they are associated on account of the epigynous character. Juncaceae, which is associated with Palmae, should be placed close to Liliaceae. Hydrocharideae, though with an inferior ovary, should be placed close to aquatic orders with non-endospermic seed.
7. The authors are silent about the phylogeny of Dicotyledons and Monocotyledons and the anomalous position of Gymnosperms.

The publication of the theories of Organic evolution by **Darwin** and by **Wallace** brought an end to the period of classification of plants based on their forms and relationships, and new systems based on the phylogenetic relationships of plants began to see the light of the day. **Julius von Sachs** (1832-1897), Professor of Botany at Wurzburg, was one of the pioneers to give up de Candollean idea of classification and substituted it by a new system in 1868. But his theory was never widely accepted.

By accepting the concept of evolution, **August Wilhelm Eichler** (1839-1887), another renowned German botanist, proposed a system of classification in 1875, and later on elaborated his own work in 1883. In the light of present-day idea of phylogeny, Eichler's system was not a truly phylogenetic one, but still it gained a wide-spread acceptance.

The best known development of a phylogenetic system is that by **Adolf Engler** (1844-1930), Professor of Botany in the University of Berlin. He published a system of classification in 1892, mainly based on that of Eichler, in *Syllabus der Vorlesungen*, meant to be used as a guide to the plants growing in the Breslau Botanic Garden. During the years 1887-1899 Engler and his associate **Prantl** brought out a monographic work, entitled *Die natürlichen Pflanzenfamilien*, in which all the known genera of plants from the

algae to the seed plants were recorded. and keys to their identification were given. Later on in 1924. Engler in collaboration with **Gilg** (and afterwards with **Diels**) published the single-volume work *Syllabus der Pflanzenfamilien.* This work has been published in several editions, the latest or the eleventh one of which came out in 1936.

Fig. 9. Adolf Engler.

Engler's system has been very widely used, especially on the continents of Europe and America. He divided the Plant Kingdom into 13 **Divisions.** In this system the seed-bearing plants (spermatophyta) are designated as *Embryophyta siphonogama* and are divided into two **Subdivisions** — *Gymnospermae* and *Angiospermae* and the Angiospermae into two **Classes**—*Monocotyledonae* and *Dicotyledonae.* The former is divided into 11 **Orders,** while the latter into two **Subclasses**—*Archichlamydeae* (or lower Dicotyledons) and *Metachlamydeae* or *Sympetalae* (or higher Dicotyledons). The former contains 30 Orders and the latter, II Orders. The Orders are further divided into **Suborders, Families,** and **Genera.** This system is based on the assumption that in flowering plants the absence of a perianth is a primitive character. Thus, the woody plants with unisexual apetalous flowers borne in aments (willows, birches, oaks, etc., often called Amentiferae) are treated as among the most primitive Dicotyledons. There are altogether 288 Families. Monocotyledons begin with *Typhaceae* and end in *Orchidaceae*, while the Dicotyledons begin with *Casuarinaceae* and end in *Compositae.*

The chief differences between this system and that of Bentham and Hooker are the amalgamation of Polypetalae and Monochlamydeae under one single group Archichlamydeae, and the Monocotyledons taking precedence over the Dicotyledons. The groups of the Families of Angiosperms have been arranged in ascending series according to the increasing complexity of the flower,

as indicated specially by the character of floral envelope. The term "Natural Order" has been replaced by the term "Family" and the "Class or Series" by the term "Order".

A tabular view of Engler's system of classification is given below :

Divisions

I. **Schizophyta—**
- 1. Class Schizomycetes
- 2. „ Schizophyceae.

II. **Myxothallophyta, Myxomycetes,** etc.

III. **Flagellatae**

IV. **Dinoflagellatae**

? **Silicoflagellatae**

V. **Bacillariophyta**

VI. **Conjugatae**

VII. **Chlorophyceae**
- 1. Class Protococcales
- 2. „ Ulotrichales
- 3. „ Siphonocladales
- 4. „ Siphonales

VIII. **Charophyta**

IX. **Phaeophyceae**

X. **Rhodophyceae**
- 1. Class Bangiales
- 2. „ Florideae

XI. **Eumycetes**
- 1. Class Phycomycetes
- 2. „ Ascomycetes
- 3. „ Protomycetes
- 4. „ Basidiomycetes

Divisions

XII. **Embryophyta Asiphonogama** (Archegoniatae)

A. Subdivision Bryophyta
- 1. Class Hepaticae
- 2. „ Musci

B. Subdivision Pteridophyta
- 1. Class Filicales
- 2. „ Sphenophyllales
- 3. „ Equisetales
- 4. „ Lycopodiales
- 5. „ Psilotales
- 6. „ Isoetales

XIII. **Embryophyta Siphonogama**

A. Subdivision Gymnospermae
- 1. Class Cycadofilicales
- 2. „ Cycadales
- 3. „ Bennettitales
- 4. „ Ginkgoales
- 5. „ Coniferae
- 6. „ Cordaitales
- 7. „ Gnetales

B. Subdivision Angiospermae
- 1. Class Monocotyledoneae
- 2. „ Dicotyledoneae
  - 1. Subclass Archichlamydeae
  - 2. „ Metachlamydeae (Sympetalae)

The classes Monocotyledoneae and Dicotyledoneae are described in detail below :

MONOCOTYLEDONEAE

Order 1. Pandanales

Fam: *1, Typhaceae; *2, Pandanaceae; 3, Sparganiaceae.

„ Helobiae

Potamogetonineae

Fam: 4, Potamogetonaceae; 5, Najadaceae; 6, Aponogetonaceae; 7, Scheuchzeriaceae.

Alismatineae

Fam: *8. Alismataceae.

Butomineae

Fam: 9. Butomaceae; *10, Hydrocharitaceae.

Order 3. TRIURIDALES

Fam: 11, Triuridaceae.

" 4. GLUMIFLORAE

Fam: *12, Gramineae; *13, Cyperaceae.

" 5. PRINCIPES

Fam: *14, Palmae.

" 6. SYNANTHAE

Fam: 15, Cyclanthaceae.

" 7. SPATHIFLORAE

Fam: *16. Araceae; *17. Lemnaceae.

" 8. FARINOSAE

Flagellarieneae

Fam: 18, Flagellariaceae.

Enantioblastae

Fam: 19. Restionaceae: 20. Centrolepidaceae: 21, Mayacaceae; 22, Xyridaceae; 23, Eriocaulaceae.

Bromilineae

Fam: 24, Thurniaceae; 25. Rapateaceae: 26, Bromeliaceae.

Commelininea

Fam: *27, Commelinaceae.

Pontederineae

Fam: *28, Pontederiaceae; 29, Cyanastraceae.

Philydrineae

Fam: 30, Philydraceae.

" 9. LILIFLORAE

Juncineae

Fam: 31, Juncaceae.

Lilineae

Fam: 32, Stemonaceae; *33, Liliaceae; 34, Haemodoraceae; *35, Amaryllidaceae; 36, Velloziaceae; 37, Taccaceae; 38, Dioscoreaceae.

Iridineae

Fam: 39, Iridaceae.

" *10. SCITAMINEAE

Fam: 40, Musaceae; 41, Zingiberaceae; 42, Cannaceae; 43, Marantaceae.

" 11. MICROSPERMAE

Burmannineae

Fam: 44, Burmanniaceae.

Gynandrae

Fam: *45, Orchidaceae.

DICOTYLEDONEAE

SUBCLASS ARCHICHLAMYDEAE (**Choripetalae** and **Apetalae**)

Order 1. VERTICILIATAE
Fam: *46, Casuarinaceae.

,, 2. PIPERALES
Fam: 47, Saururaceae; *48, Piperaceae; 49, Chloranthaceae; 50, Lacistemonaceae.

,, 3. SALICALES
Fam: *51, Salicaceae.

,, 4. GARRYALES
Fam: 52, Garryaceae.

,, 5. MYRICALES
Fam: 53, Myricaceae.

,, 6. BALANOPSIDALES
Fam: 54, Balanopsidaceae.

,, 7. LEITNERIALES
Fam: 55, Leitneriaceae.

,, 8. JUGLANDALES
Fam: 56, Juglandaceae.

,, 9. BATIDALES
Fam: 57, Batidaceae.

,, 10. JULIANIALES
Fam: 58, Julianiaceae.

,, 11. FAGALES
Fam: 59, Betulaceae; 60, Fagaceae.

,, 12. URTICALES
Fam: 61, Ulmaceae; *62, Moraceae; *63, Urticaceae.

,, 13. PROTEALES
Fam: 64, Proteaceae.

,, 14. SANTALALES
Santalineae
Fam: 65, Mezodendraceae; *66, Santalaceae; 67, Opiliaceae; 68, Grubbiaceae; 69, Olacaceae; 70, Octoknemataceae.
Loranthineae
Fam: *71, Loranthaceae.
Balanophorineae
Fam: 72, Balanophoraceae.

,, 15. ARISTOLOCHIALES
Fam: 73, Aristolochiaceae; 74, Rafflesiaceae; 75, Hydnoraceae.

,, 16. POLYGONALES
Fam: *76, Polygonaceae.

,, 17. CENTROSPERMAE
Chenopodiineae
Fam: *77, Chenopodiaceae; *78, Amaranthaceae.
Phytolaccineae
Fam: *79, Nyctaginaceae; 80, Cynocrambaceae; 81, Phytolaccaceae; 82, Aizoaceae.

Portulacineae

Fam: *83, Portulacaceae; 84, Basellaceae.

Caryophyllineae

Fam: *85, Caryophyllaceae.

Order 18. RANALES

Nymphaeineae

Fam: *86, Nymphaeaceae; 87, Ceratophyllaceae.

Trochodendrineae

Fam: 88, Trochodendraceae; 89, Cercidiphyllaceae.

Ranunculineae

Fam: *90, Ranunculaceae; 91, Lardizabalaceae; 92, Berberidaceae; 93, Menispermaceae.

Magnolineae

Fam: *94, Magnoliaceae; 95, Himantandraceae; 96, Calycanthaceae; 97, Lactoriadaceae; *98, Anonaceae; 99, Eupomatiaceae; 100, Myristicaceae; 101, Gomortegaceae; 102, Monimiaceae; *103, Lauraceae; 104, Hernandiaceae.

" 19. RHOEADALES

Rhoeadineae

Fam: *105, Papaveraceae.

Capparidineae

Fam: *106, Capparidaceae; *107, Cruciferae; 108, Tovariaceae.

Resedineae

Fam : 109, Resedaceae.

Moringineae

Fam: 110, Moringaceae.

" 20. SARRACENIALES

Fam: 111, Sarraceniaceae; 112, Nepenthaceae; 113, Droseraceae.

" 21. ROSALES

Podostemonineae

Fam: 114, Podostemonaceae; 115, Hydrostachyaceae.

Saxifragineae

Fam: *116, Crassulaceae; 117, Cephalotaceae; 118, Saxifragaceae; 119, Pittosporaceae; 120, Brunelliaceae; 121, Cunoniaceae; 122, Myrothamnaceae; 123, Bruniaceae; 124, Hamamelidaceae; 125, Eucommiaceae.

Rosineae

Fam; 126, Platanaceae; 127, Crossosomataceae; *128, Rosaceae; 129, Connaraceae; *130, Leguminosae.

" 22. PANDALES

Fam : 131, Pandaceae.

" 23. GERANIALES

Geraniineae

Fam: *132, Geraniaceae; 133, Oxalidaceae; 134, Tropaeolaceae; *135, Linaceae; 136, Humiriaceae; 137, Erythroxylaceae; 138, Zygophyllaceae; 139, Cneoraceae; *140,

Rutaceae; 141, Simarubaceae; 142, Burseraceae; *143, Meliacea.

Malpighineae

Fam: 144, Malpighiaceae; 145, Trigoniaceae; 146, Vochysiaceae.

Polygalineae

Fam: 147, Tremandraceae; 148, Polygalaceae.

Dichapetalineae

Fam: 149, Dichapetalaceae.

Tricoccae

Fam: *150. Euphorbiaceae.

Callitrichineae

Fam: 151, Callitrichaceae.

Order 24. SAPINDALES

Buxineae

Fam: 152, Buxaceae.

Empetrineae

Fam: 153, Empetraceae.

Coriarineae

Fam: 154, Coriariaceae.

Limnanthineae

Fam: 155, Limnanthaceae.

Anacardineae

Fam: *156, Anacardiaceae.

Celastrineae

Fam: 157, Cyrillaceae; 158, Pentaphylacaceae; 159, Corynocarpaceae; 160, Aquifoliaceae; 161, Celastraceae, 162, Hippocrateaceae; 163, Salvadoraceae; 164, Stackhousiaceae; 165, Staphyleaceae.

Icacinineae

Fam: 166, Icacinaceae.

Sapindineae

Fam: 167, Aceraceae; 168, Hippocastanaceae; *169, Sapindaceae.

Sabineae

Fam: 170, Sabiaceae.

Melianthineae

Fam: 171, Melianthaceae.

Balsaminineae

Fam: 172, Balsaminaceae.

" 25. RHAMNALES

Fam: *173, Rhamnaceae; *174, Vitaceae.

" 26. MALVALES

Elaeocarpineae

Fam: 175, Elaeocarpaceae.

Chlaenineae

Fam: 176, Chlaenaceae.

Malvineae

Fam: 177, Gonystilaceae; *178, Tiliaceae; *179, Malvaceae; *180, Bombacaceae; *181, Sterculiaceae.

Scytopetalineae

Fam: 182, Scytopetalaceae.

Order 27. PARIETALES

Camellineae

Fam: 183, Dilleniaceae; 184, Eucryphiaceae; 185, Ochnaceae; 186, Caryocaraceae; 187, Maregraviaceae; 188, Quinaceae; 189, Camelliaceae Theaceae ; *190, Guttiferae; *191, Dipterocarpaceae.

Tamaricineae

Fam: 192, Elatinaceae; 193, Frakeniaceae; 194, Tamaricaceae.

Foquierineae

Fam: 195, Foquieraceae.

Cistineae

Fam: 196, Cistaceae; 197, Bixaceae.

Cochlospermineae

Fam: 198, Cochlospermaceae.

Flacourtineae

Fam: 199, Winternaceae; *200, Violaceae; 201, Flacourtiaceae; 202, Stachyuraceae; 203, Turneraceae; 204, Malesherbiaceae; *205, Passifloraceae; 206, Achariaceae.

Papayineae

Fam : 207, Caricaceae.

Loasineae

Fam : 208, Loasaceae.

Datiscineae

Fam : 209, Datiscaceae.

Begonineae

Fam: 210, Begoniaceae.

Ancistrocladineae

Fam: 211, Ancistrocladaceae.

" 28. OPUNTIALES

Fam: *212, Cactaceae.

" 29. MYRTIFLORAE

Thymelaeineae

Fam: 213, Geissolomataceae; 214, Penaceaceae; 215, Oliniaceae; 216, Thymelaeaceae; 217, Elaeagnaceae.

Myrtineae

Fam: *218, Lythraceae; 219, Heteropyxidaceae; 220, Sonneratiaceae; 221, Punicaceae; 222, Lecythidaceae; *223, Rhizophoraceae; 224, Nyssaceae; 225, Alangiaceae; *226, Combretaceae; *227, Myrtaceae; *228, Melastomaceae; 229, Oenotheraceae; 230, Halorrhagaceae.

Hippuridineae

Fam: 231, Hippuridaceae.

Cynomorineae
Fam: 232. Cynomoriaceae.

Order 30. UMBELLIFLORAE
Fam: 233. Araliaceae; *234. Umbelliferae; 235. Cornaceae.

SUBCLASS METACHLAMYDEAE (**Sympetalae**)

Order 1. ERICALES

Diapensiales
Fam: 236, Diapensiaceae.

Ericineae
Fam: 237, Clethraceae; 238, Pirolaceae; 239, Lennoaceae; 240, Ericaceae; 241, Epacridaceae.

" 2. PRIMULALES
Fam: 242, Theophrastacere; 243, Myrsinaceae; 244, Primulaceae.

" 3. PLUMBAGINALES
Fam: 245, Plumbaginaceae.

" 4. EBENALES

Sapotineae
Fam: *246, Sapotaceae; 247, Hoplestigmataceae.

Diospyrineae
Fam: 248, Ebenaceae; 249, Symplocaceae; 250, Sytracaceae.

" 5. CONTORTAE

Oleineae
Fam: *251, Oleaceae.

Gentianineae
Fam: 252, Loganiaceae, *253, Gentianaceae; *254, Apocynaceae; *255, Asclepiadaceae.

" 6. TUBIFLORAE

Convolvulineae
Fam: *256, Convolvulaceae; 257, Polemoniaceae.

Boraginineae
Fam: 258, Hydrophyllaceae; *259, Boraginaceae.

Verbenineae
Fam: *260, Verbenaceae; *261, Labiatae.

Solanineae
Fam: 262, Nolanaceae; *263, Solanaceae; *264, Scrophulariaceae; *265, Bignoniaceae; *266, Pedaliaceae; 267, Martyniaceae; 268, Orobanchaceae; 269, Gesneriaceae; 270, Columelliaceae; *271, Lentibulariaceae; 272, Globulariaceae.

Acanthineae
Fam: *273, Acanthaceae.

Myoporineae
Fam: 274, Myoporaceae.

Phrymineae
Fam: 275, Phrymaceae.

" 7. PLANTAGINALES
Fam: 276, Plantaginaceae.

Order 8. RUBIALES

Fam: *277, Rubiaceae; 278, Caprifoliaceae; 279, Adoxaceae; 280, Valerianaceae; 281, Dipsacaceae.

„ 9. CUCURBITALES·

Fam: *282, Cucurbitaceae.

„ 10. CAMPANULATAE

Fam: 283, Campanulaceae; 284, Goodeniaceae; 285, Brunoniaceae; 286, Stylidiaceae; 287, Calyceraceae; *288, Compositae.

Merits and Demerits

Merits:

1. The chief merit lies in the broad treatment of the entire Plant Kingdom, its excellent illustrations and its phylogenetic arrangement of many groups.
2. Amalgamation of Polypetalae and Monochlamydeae into Archichlamydeae.
3. Orchidaceae is placed at the end of the Monocotyledons and Compositae at the end of the Dicotyledons, since they are most highly evolved.
4. Juncaceae, Iridaceae and Amaryllidaceae are placed closer to Liliaceae.

Demerits:

1. The union of Choripetalae and Apetalae is an improvement over that of Bentham and Hooker's system, but in other respects not so—it is a far cry from a salix to a buttercup.
2. Amentiferae and Centrospermae are placed at the beginning of the Dicotyledons even before Ranales. The foliar nature of carpels is fatal to the primitiveness of Amentiferae. Centrospermae are highly specialized. Caryophyllaceae with two whorls of perianth, central placentation and syncarpous ovary can never precede Ranales.
3. Grouping of all sympetalous forms under one assemblage (Metachiamydeae) has led to Orders being distantly removed.
4. Monocotyledons are placed before the Dicotyledons. It is generally agreed that Monocotyledons have arisen from Dicotyledons by reduction.
5. Placing of Helobiae between two more advanced Orders, Pandanales and Glumiflorae.
6. Araceae are inserted a long way before the Liliaceae, from which they have been derived (*not vice versa*).
7. Recent works on the fossil records give little support to this system.

Richard von Wettstein (1862-1931), a German botanist, published his *Handbuch der systematischen Botanik* in 1901, in which he presented his ideas on the phylogenetic classification of plants. Though the basic structure of his system is somewhat like that of Engler's, yet in general his was a better phylogenetic classification

than that suggested by Engler. But the system was never widely accepted.

Charles E. Bessey (1845-1915) of the University of Nebraska was the first American who made a significant contribution to a really phylogenetic classification of plants. He thoroughly rejected the ideas of Eichler and Engler, and based his system mainly on that of Bentham and Hooker re-arranged and re-named in the majority of cases, basing on evolutionary principles. Bessey regarded the seed plants as polyphyletic in origin, which had developed along three independent lines. Of these, in his system of classification, he dealt with the *Anthophyta* (Angiosperms) only. He classified the Angiosperms into two main **Classes**—*Alternifoliae* (Monocotyledoneae) and *Oppositifoliae* (Dicotyledoneae). Each of these classes was subdivided into two **Subclasses**—*Strobiloideae* and *Cotyloideae*. These Subclasses under the Class Alternifoliae were again divided into several **Orders,** each consisting of a few to one **Family.** The Subclass under the Class Oppositifoliae, on the other hand, were first divided into some **Super Orders,** which, in their turn, were further subdivided into **Orders** and **Families.**

Fig. 10. Charles Edwin Bessey.

The system of **Alfred Baston Rendle** (1865-1938), late Keeper of the Department of Botany, British Museum of Natural History, London, was published in his book *Classification of Flowering plants*, Vols. I (1904) and II (1925).

This system follows in the main that of Engler with some deviations. The Archichlamydeae has been broken up into **Grades,** *Monochlamydeae* and *Dialypetalae*, but Sympetalae has been arranged under several **Orders,** and these have been distributed under the three grades mentioned above corresponding to the grades of differentiation of the floral structure.

The first Grade, Monochlamydeae, includes on the whole

comparatively simple types of flowers which are either naked or have a monochlamydeous bract-like perianth. It includes 13 Orders and 31 Families.

In the second Grade, Dialypetalae, the Orders are arranged as far as possible in the ascending sequence. It is characterized by "a diminution in the number of members of each whorl, and in the higher groups, a tendency to their union, a whorled instead of a spiral arrangement of parts, a passage from hypogyny through perigyny to epigyny and a development of zygomorphic form from a regular flower." It includes 17 Orders and 95 Families.

The last Grade, Sympetalae, includes 11 Orders and 51 Families. It represents still higher grade of floral development and comprises firstly, a pentacyclic group with typically two whorls of stamens; secondly, a higher group with tetracyclic hypogynous flowers, and thirdly, a group with tetracyclic epigynous flowers in which the highest form of floral complexity is attained.

Fig. 11. John Hutchinson.

In the classification of Monocotyledons slight deviations from Engler are also noticeable. The arrangement, however, follows closely with that of Engler.

John Hutchinson (1884—) of the Royal Botanic Gardens, Kew, England, has proposed a new system of classification on strictly phylogenetic lines in his *The Families of Flowering Plants.* The first volume on Dicotyledons was published in 1926, and the second on Monocotyledons in 1934.* Its chief feature is the renewal of the ancient emphasis on the distinction between arborescent and herbaceous habits, in conjunction with other floral characters. Hutchinson opines that Ranales and Magnoliales form the starting point of the phylogenetic system, the former giving rise to other Orders that are mostly herbaceous, and the latter to

*Recently a revised second edition of the book has been published in 1960.

those ones that are mostly woody, and from these branches each of the existing families has been derived by specialization. In his system Hutchinson established that plants with sepals and petals are phylogenetically ancient than those without them. His system is woven round the following criteria : (1) of the free and connate or adnate parts, the latter are the more recent ; (2) the spiral arrangement of parts is more primitive than the cyclic one; (3) numerous, free stamens have evolved before the few and united ones, and (4) hermaphrodite flowers have come earlier than the unisexual ones. In this system resemblances are emphasized rather than differences. Hutchinson has distributed Monochlamydeae of Bentham and Hooker among Polypetalae, and at the same time has deemed them as more recent. The Monocotyledons have come later than Dicotyledons and they have a polyphyletic origin from Ranunculaceae and its allies. He opines that Amentiferae are more evolved due to their united carpels, and the anemophilous pollination found therein cannot be regarded as a primitive one. On the whole, this rearrangement of the Orders of Bentham and Hooker's system has been made on a phylogenetic basis. Hutchinson has classified the flowering plants into two **Phyla**—*Gymnospermae* and *Angiospermae*. Angiospermae have been divided into two **Subphyla** —*Dicotyledones* and *Monocotyledones*. The former have been divided into two **Divisions**—*Archichlamydeae* and *Metachlamydeae;* and the latter into three **Divisions**—*Calyciferae* (calyx-bearers), *Corolliferae* (corolla-bearers) and *Glumiflorae*. The Divisions are further subdivided into **Orders**, **Families** and **Genera**. There are altogether 105 Orders with 332 Families. The Dicotyledones begin with Magnoliaceae and end in Labiatae, while the Monocotyledones begin with Butomaceae and end in Gramineae. The Orders here recognized are much smaller concepts than those of Bentham and Hooker or of Engler, and correspond more with the Suborders of the latter.

The Subphyla Dicotyledones and Monocotyledones are described in detail below :

DICOTYLEDONES

DIVISION I. ARCHICHLAMYDEAE

Order 1. MAGNOLIALES

Fam: *1, Magnoliaceae; 2, Winteraceae; 3, Schizandraceae; 4, Himatandraceae; 5, Lactoridaceae; 6 Trochodenuraceae; 7, Cercidiphyllaceae.

Order 2. ANONALES
Fam: *8, Anonaceae; 9, Eupomatiaceae.

„ 3. LAURALES
Fam: 10, Monimiaceae; *11, Lauraceae; 12, Gomortegaceae; 13, Hernandiaceae; 14, Myristicaceae.

„ 4. RANALES
Fam: *15, Ranunculaceae: 16, Cabombaceae; 17, Ceratophyllaceae; *18, Nymphaeaceae.

„ 5. BERBERIDALES
Fam: 19, Berberidaceae; 20, Circaeasteraceae; 21, Lardizabalaceae; 22, Sargentadoxaceae; 23, Menispermaceae.

„ 6. ARISTOLOCHIALES
Fam: 24, Aristolochiaceae; 25, Cytinaceae; 26, Hydnoraceae; 27, Nepenthaceae.

„ 7. PIPERALES
Fam: *28, Piperaceae; 29, Saururaceae; 30, Chloranthaceae; 31, Lacistemaceae.

„ 8. RHOEADALES
Fam: *32, Papaveraceae; 33, Fumariaceae.

„ 9. LOASALES
Fam: 34, Turneraceae; 35, Loasaceae.

„ 10. CAPPARIDALES
Fam: *36, Capparidaceae; 37, Moringaceae; 38, Tovariaceae.

„ 11. CRUCIALES
Fam: *39, Cruciferae.

„ 12. VIOLALES
Fam: *40, Violaceae; 41, Resedaceae.

„ 13. POLYGALALES
Fam: 42, Polygalaceae; 43, Trigoniaceae; 44, Vochysiaceae.

„ 14. SAXIFRAGALES
Fam: *45, Crassulaceae; 46, Cephalotaceae; 47, Saxifragaceae.

„ 15. SARRACENIALES
Fam: 48, Droseraceae; 49, Sarraceniaceae.

„ 16. PODOSTEMONALES
Fam: 50, Podostemonaceae; 51, Hydrostachyaceae.

„ 17. CARYOPHYLLALES
Fam: 52, Elatinanceae; *53, Caryophyllaceae; 54, Molluginaceae; 55, Ficoidaceae (Aizoaceae); *56, Portulacaceae.

„ 18. POLYGONALES
Fam: *57, Polygonaceae; 58, Illecebraceae.

„ 19. CHENOPODIALES
Fam: 59, Phytolaccaceae; 60, Cynocrambaceae; *61, Chenopodiaceae; 62, Batidaceae; *63, Amarantaceae; 64, Basellaceae.

„ 20. GERANIALES
Fam: *65, Linaceae; 66, Zygophyllaceae; *67, Geraniaceae; 68, Limnanthaceae; 69, Oxalidaceae; 70, Tropaeolaceae; 71, Balsaminaceae.

Order 21. LYTHRALES
Fam: *72, Lythraceae; 73, Crypteroniaceae; 74, Sonneratiaceae; 75, Punicaceae; 76, Oliniaceae; *77, Onagraceae; 78, Holorrhagaceae; 79, Callitrichiaceae.

„ 22. THYMELAEALES
Fam: 80, Geissolomataceae; 81, Thymeleaceae; 82, Penaeaceae; *83, Nyctaginaceae.

„ 23. PROTEALES
Fam: 84, Proteaceae.

„ 24. DILLENIALES
Fam: 85, Dilleniaceae; 86, Crossosomateceae.

„ 25. CORIARIALES
Fam: 87, Coriariaceae.

„ 26. PITTOSPORALES
Fam: 88, Pittosporaceae; 89, Byblidaceae; 90, Tremandaceae.

„ 27. BIXALES
Fam: 91, Bixaceae; 92, Cochlospermaceae; 93, Flacourtiaceae; 94, Samydaceae; 95, Canellaceae; 96, Cistaceae.

„ 28. TAMARICALES
Fam: 97, Frankeniaceae; 98, Tamaricaceae; 99, Fouquieraceae.

„ 29. PASSIFLORALES
Fam: 100, Malesherbiaceae; *101, Passifloraceae; 102, Achariaceae.

„ 30. CUCURBITALES
Fam: *103, Cucurbitaceae; 104, Begoniaceae; 105, Datiscaceae; 106, Caricaceae.

„ 31. CACTALES
Fam: *107, Cactaceae.

„ 32. THEALES
Fam: 108, Theaceae (Ternstroemiaceae); 109, Medusagynaceae; 110, Marcgraviaceae; 111, Caryocaraceae; 112, Actinidiaceae; 113, Saurauiaceae; 114, Ochnaceae; 115, Ancistrocladaceae; *116, Dipterocarpaceae; 117, Chlaenaceae.

„ 33. MYRTALES
Fam: *118, Myrtaceae; 119, Lecythidaceae; *120, Melastomaceae; *121, Combretaceae; *122, Rhizophoraceae.

„ 34. GUTTIFERALES
Fam: 123, Hypericaceae; 124, Eucryphiaceae; 125, Quinaceae; *126, Guttiferae.

„ 35. TILIALES
Fam: 127, Scytopetalaceae; *128, Tiliaceae; 129, Gonystylaceae; *130, Sterculiaceae; *131, Bombacaceae.

„ 36. MALVALES
Fam: *132, Malvaceae.

„ 37. MALPIGHIALES
Fam: 133, Malpighiaceae; 184, Humiriaceae; 135, Erythroxylaceae.

Order 38. Euphorbiales

Fam: *136, Euphorbiaceae.

„ 39. Cunoniales

Fam: 137, Cunoniceae; 138, Brunellaceae; 139, Escalloniaceae; 140, Greylaceae: 141, Grosasulariaceae, 142, Hydrangeaceae.

„ 40. Rosales

Fam: *143, Rosaceae; 144, Chailletiaceae; 145, Calycanthaceae.

„ 41. *Leguminosae

Fam: 146, Caesalpiniaceae; 147, Mimosaceae; 148, Papilionaceae.

„ 42. Hamamelidales

Fam: 149, Bruniaceae; 150, Stachyuraceae, 151, Hamamelidaceae; 152, Eucommiaceae; 153, Myrothamnaceae; 154, Buxaceae; 155, Plantanaceae.

„ 43. Salicales

Fam: *156, Salicaceae.

„ 44. Garryales

Fam: 157, Garryaceae.

„ 45. Leitneriales

Fam: 158, Leitnerlaceae.

„ 46. Myricales

Fam: 159, Myricaceae.

„ 47. Balanopsidales

Fam: 160, Balanopsidaceae.

„ 48. Fagales

Fam: 161, Betulaceae; 162, Corylaceae; 163, Fagaceae.

„ 49. Casuarinales

Fam: *164, Casuarinaceae.

„ 50. Urticales

Fam: 165, Ulmaceae; 166, Barbeyaceae; *167, Moraceae; 168, Scyphostegiaceae; *169, Urticaceae; 170, Cannabinaceae.

„ 51. Celastrales

Fam: 171, Aquifoliaceae; 172, Empetraceae; 173, Celastraceae; 174, Corynocarpaceae; 175, Cyrillaceae; 176, Cneoraceae; 177, Pandaceae; 178, Hippocrateaceae; 179, Icacinaceae; 180, Salvadoraceae; 181, Stackhousiaceae.

„ 52. Olacales

Fam: 182, Olacaceae; 183, Opiliaceae.

„ 53. Santalales

Fam: 184, Octoknemataceae; *185, Loranthaceae; *186, Santalaceae; 187, Grubbiaceae; 188, Myzodendraceae; 189, Balanophoraceae.

„ 54. Rhamnales

Fam: *190, Rhamnaceae; 191, Elaeaginaceae; 192, Hetropyxidaceae; *193, Ampelidaceae (Vitaceae).

„ 55. Rutales

Fam: *194, Rutaceae; 195, Simarubaceae; 196, Burseraceae.

„ 56. Meliales

Fam: *197, Meliaceae.

Order 57. Sapindales
Fam: *198, Sapindaceae; 199, Akaniaceae; 200, Aceraceae; 201, Sabiaceae: 202, Melianthaceae; 203, Didieraceae; 204, Staphyleaceae; *205, Anacardiaceae; 206, Connaraceae.

„ 58. Juglandales
Fam: 207, Jugalandaceae; 208, Julianiaceae.

„ 59. Umbelliflorae
Fam: 209, Cornaceae; 210, Alangiaceae; 211, Nyssaceae; 212, Araliaceae; *213, Umbelliferae.

DIVISION II. METACHLAMYDEAE

Order 60. Ericales
Fam: 214, Clethraceae; 215, Ericaceae; 216, Vacciniaceae; 217, Epacridaceae; 218, Monotropaceae; 219, Diapensiaceae; 220, Lennoaceae.

„ 61. Ebenales
Fam: 221, Ebenaceae; *222, Sapotaceae.

„ 62. Myrsinales
Fam: 223, Myrsinaceae.

„ 63. Styracales
Fam: 224, Styracaceae; 225, Symplocaceae; 226, Diclidantheraceae; 227, Lissocarpaceae.

„ 64. Loganiales
Fam: 228, Loganiaceae; *229, Oleaceae.

„ 65. Apocynales
Fam: *230, Apocynaceae; *231, Asclepiadaceae.

„ 66. Rubiales
Fam: *232, Rubiaceae; 233, Caprifoliaceae.

„ 67. Asterales
Fam: 234, Adoxaceae; 235, Valerianaceae; 236, Dipsacaceae; 237, Calyceraceae; *238, Compositae.

„ 68. Gentianales
Fam: *239, Gentianaceae.

„ 69. Primulales
Fam: 240, Primulaceae; 241, Plumbaginaceae.

„ 70. Plantaginales
Fam: 242, Plantaginaceae.

„ 71. Campanales
Fam: 243, Campanulaceae; 244, Lobeliaceae; 245, Goodeniaceae; 246, Stylidiaceae.

„ 72. Polemoniales
Fam: 247, Polemoniaceae; 248, Hydrophyllaceae.

„ 73. Boraginales
Fam: *249, Boraginaceae.

„ 74. Solanales
Fam: *250, Solanaceae; *251, Convolvulaceae.

Order 75. PERSONALES
Fam: *252, Scrophulariaceae; 253, Orobanchaceae; *254, Lentibulariaceae; 255, Columelliaceae; 256, Gesneriaceae; *257, Bignoniaceae; *258, Pedaliaceae; *259, Acanthaceae.

" 76. LAMIALES
Fam: 260, Globulariaceae; 261, Myoporaceae; 262, Selaginaceae; *263, Verbenaceae; *264, Labiatae.

MONOCOTYLEDONES

DIVISION I. CALYCIFERAE

Order 77. BUTOMALES
Fam: 265, Butomaceae; *266, Hydrocharitaceae.

" 78. ALISMATALES
Fam: *267, Alismataceae; 268, Scheuchzeriaceae; 269, Petrosaviaceae.

" 79. TRIURIDALES
Fam: 270, Triuridaceae.

" 80. JUNCAGINALES
Fam: 271, Juncaginaceae; *272, Liliaceae (Heterostylaceae); 273, Posidoniaceae.

" 81. APONOGETONALES
Fam: 274, Aponogetonaceae; 275, Zosteraceae.

" 82. POTAMOGETONALES
Fam: 276, Potamogetonaceae; 277, Ruppiaceae.

" 83. NAJADALES
Fam: 278, Zannichelliaceae; 279, Najadaceae.

" 84. COMMELINALES
Fam: *280, Commelinaceae; 281, Flagellariaceae; 282, Mayaceae.

" 85. XYRIDALES
Fam: 283, Zyridaceae; 284, Rapateaceae.

" 86. ERIOCAULALES
Fam: 285, Eriocaulaceae.

" 87. BROMELIALES
Fam: 286, Bromeliaceae.

" 88. ZINGIBERALES
Fam: *287, Musaceae; 288, Strelitziaceae; 289, Lowiaceae; *290, Zingiberaceae; *291, Cannaceae; *292, Marantaceae.

DIVISION II. COROLLIFERAE

Order 89. LILIALES
Fam: *293, Liliaceae; 294, Tecophilacaceae; 295, Trilliaceae; *296, Pontederiaceae; 297, Smilaceae; 298, Ruscaceae.

" 90. ALSTROEMERIALES
Fam: 299, Alstroemeriaceae; 300, Petermanniaceae; 301, Philesiaceae.

Order 91. ARALES
Fam: *302, Araceae; *303, Lemnaceae.

,, 92. TYPHALES
Fam: 304, Sparganiaceae; *305, Typhaceae.

,, 93. AMARYLLIDALES
Fam: *306, Amaryllidaceae.

,, 94. IRIDALES
Fam: 307, Iridaceae.

,, 95. DIOSCOREALES
Fam: 308, Stenomeridaceae; 309, Trichapodaceae; 310, Roxburghiaceae; 311, Dioscoreaceae.

,, 96. AGAVALES
Fam: 312, Xanthorrhoeaceae; 313, Agavaceae.

,, 97. PALMALES
Fam: *314, Palmae.

,, 98. PANDANALES
Fam: *315, Pandanaceae.

,, 99. CYCLANTHALES
Fam: 316, Cyclanthaceae.

,, 100. HEAMODORALES
Fam: 317, Haemodoraceae; 318, Hypoxidaceae; 319, Velloziaceae; 320, Apostasiaceae; 321, Taccaceae; 322, Philydraceae.

,, 101. BURMANNIALES
Fam: 323, Burmanniaceae; 324, Thismiaceae; 325, Corsiaceae.

,, 102. ORCHIDALES
Fam: *326, Orchidaceae.

DIVISION III. GLUMIFLORAE

Order 103. JUNCALES
Fam: 327, Juncaceae; 328, Thurniaceae; 329, Centrolepidaceae; 330, Restienaceae.

,, 104. CYPERALES
Fam: *331, Cyperaceae.

,, 105. GRAMINALES
Fam: *332, Gramineae.

Merits and Demerits

Merits:

1. The placing of Ranunculaceae and its allies at the beginning of the Dicotyledons.
2. Amentiferae is deemed as a reduced form and is placed later in the Dicotyledons.
3. In Dicotyledons the woody forms are derived from the Magnolian stock and herbaceous ones from the Ranunculian one.
4. Dicotyledons at first started as bisexual, flowers while unisexual ones are derived from them by reduction.
5. Monocotyledons are derived from Dicotyledons, and the origin is polyphylectic from Ranunculaceae and its allies.

6. Helobiae is placed at the beginning of Monocotyledons.
7. Re-shuffling of Liliaceae and Amaryllidaceae solely on inflorescence characters, irrespective of epigyny or hypogyny.
8. The foliar origin of carpels has become the basis of this system of classification.
9. Recent cytogenetical and anatomical studies support this contention.

Demerits:
1. Delimitation of small groups based on resemblances. Relative groups as a result have been shown to be distantly related.
2. Polyphylectic origin of Amentiferae from herbaceous and woody forms.
3. Polyphylectic origin of such natural groups as Asterales, Umbelliferales, Urticales, etc.
4. Sometimes too much stress is laid on habit and habitat.
5. In Monocotyledons related Orders like Scitamineae and Microspermae are placed apart.
6. So far Zingiberaceae is concerned, it is separated from Liliales because the former is rhizomatic while the latter is bulbous.
7. The origin of Monocotyledons from a single source Ranales is unlikely (as postulated in his Monocotyledons).
8. The phylogenetic line demarcating Sympetalae from Dialypetalae should be removed.
9. Proteales of Apetalae though characterized by woody habit have been derived from herbaceous Ranales.

Oswald Tippo* (1911—) of Illinois University, U. S. A., published an outline of a suggested system of classification in 1942. In this system the entire Plant Kingdom has been divided into two **Subkingdoms,** each one of which consists of several **Phyla** and **Subphyla.** All the vascular plants (Pteridophytes, Gymnosperms and Angiosperms) have been placed under one Phylum, the *Tracheophyta.* An outline of Tippo's classification is given below :

Plant Kingdom

I. SUBKINGDOM: **Thallophyta** ..

Phylum	Cyanophyta (blue-green algae)	"Algae" of older system
,,	Euglenophyta (euglenoids)	
,,	Chlorophyta (green algae)	
,,	Chrysophyta (yellow green algae, golden-brown algae, and diatoms) ..	
,,	Pyrrophyta (cryptomonads and dinoflagellate)	
,,	Phaeophyta (brown algae)	
,,	Rhodophyta (red algae)	

* Chronica Botanica, 7 : 5 : 203-206, 1042.

Phylum Schizomycophyta (bacteria)
,, Myxomycophyta (slime moulds)
,, Eumycophyta (true fungi)

"Fungi" of older system

II. SUBKINGDOM: **Embryophyta**

Phylum Bryophyta (or Atracheata)
Class Musci (mosses)
,, Hepaticae (liverworts)
,, Anthocerotae (hornworts)

"Bryophytes" of older system

Phylum Tracheophyta (or Tracheata)—vascular plants

Subphylum Psilopsida
Class Psilophytineae
Order *Psilophytales*
,, *Psilotales*

Subphylum Lycopsida (club-mosses)
Class Lycopodineae
Order *Lycopodiales* (club-mosses)
,, *Selaginellales* (small club-mosses)
,, *Lepidodendrales* (giant club-mosses)
,, *Pleuromeiales*
,, *Isoetales* (quillworts)

Subphylum Sphenopsida (horsetails)
Class Equisetineae
Order *Hyeniales*
,, *Sphenophyllales*
,, *Equisetales* (horsetails)

Subphylum Pteropsida
Class Filicineae (ferns)
Order *Coenopteridales*
,, *Ophioglossales*
,, *Marattiales*
,, *Filicales*

"Pteridophytes" of older system

Class Gymnospermae (conifers and their allies)

Subclass Cycadophytae
Order *Cycadofilicales* (or Pteridospermae)—seed ferns
,, *Bennettitales*
,, *Cycadales*—cycads

"Spermatophytes" of older system

Subclass Coniferophytae Order *Cordaitales* " *Ginkgoales*—maiden-hair tree " *Coniferales*—conifers " *Gnetales* **Class Angiospermae**—flowering plants **Subclass Dicotyledoneae** **Subclass Monocotyledoneae**	"Spermatophytes" of older system

Recently, **R. C. Maclean** and **W. R. Ivimey-Cook,** two British authors, in their *Textbook of Theoretical Botany, Vol. II* (1956), have suggested an outline classification of the Angiosperms, in which they have made a departure from the existing systems. These authors have rejected Bentham and Hooker's Apetalae, and have accepted Engler's Archichlamydeae and Metachlamydeae. They have retained the Ranales, however, in their age-old traditional position as the most primitive Order in the Plant Kingdom, and have placed the Dicotyledones before the Monocotyledones in opposition to Engler's idea. Moreover, they do not follow Hutchinson even in not accepting the separation of the Orders into two distinct lines,—one predominantly herbaceous, and the other predominantly woody.

Characters used in a phylogenetic system

In a phylogenetic system the following salient characters are usually taken into consideration for differentiating a "primitive plant" from an "advanced one."

Primitive characters	*Advanced characters*
(a) *Morphological:*	
1. Plants woody and erect, monoecious.	1. Plants herbaceous and weak, dioecious.
2. Leaves simple, net-veined, spirally arranged.	2. Leaves parallel-veined, compound with opposite or whorled phyllotaxy.
3. Flowers regular, solitary, bisexual, hypogynous, acyclic, radially symmetrical.	3. Flowers irregular, aggregated, unisexual or neuter, perigynous or epigynous, cyclic, bilaterally symmetrical.
4. Perianth consists of like segments.	4. Perianth absent or consists of dissimilar segments.
5. Petals free.	5. Petals united or absent.
6. Stamens numerous and free.	6. Stamens a few and united.

7. Carpels numerous and free.	7. Carpels solitary, or a few and united.
8. Placentation axile.	8. Placentation parietal.
9. Ovules numerous.	9. Ovules solitary or central.
10. Fruit simple or aggregate.	10. Fruit multiple.
11. Seed endospermic with a small, straight embryo.	11. Seed non-endospermic with a large, curved embryo.
b) Anatomical:	
12. Cortical cells contain chloroplasts.	12. Cortical cells are without chloroplasts.
13. Bundles of the stem are collateral, open and arranged in a ring.	13. Bundles of the stem are collateral, closed and scattered.
14. Tracheids present and vessels less prominent.	14. Tracheids usually absent and vessels predominant.
15. Vessels with scalariform thickenings and scalariform perforations.	15. Vessels with pitted thickenings and simple perforations.

Alternation of generations

Every plant possesses what is termed a **life history,** *i.e.*, every plant has got a beginning, passes through certain stages, attains maturity, reproduces, becomes old and ultimately dies. All these changes from the beginning to the end collectively constitute its life history. In all groups of plants, beginning from the thallophytes right up to the spermatophytes, there is very frequently found an alternation of two stages, or phases, or generations in the life history of the individual. The two alternating generations may be morphologically distinct and independent individuals, or they may not be so. That stage, which bears the sex organs, is called the **gametophyte** or **sexual generation,** and that which bears the asexual bodies, called **spores,** is known as the **sporophyte** or **asexual generation**. The spore produced by the sporophyte always develops into a gametophyte, while the zygote produced by the gametophyte develops into a sporophyte. This phenomenon of alternation between the gametophyte and the sporophyte is spoken of as the '*alternation of generations*'.

Generally, the alternation of the nuclear phases is closely associated with the alternation of generations. Thus, the sporophyte nucleus is **diploid** (with $2n$ number of chromosomes), while the gametophyte nucleus is **haploid** (with n number of chromosomes). The gametophyte or the haploid generation begins with meiotic division, while the sporophyte or diploid generation starts with

sexual fusion (conjugation or fertilization and with the formation of the zygote (zygospore or oospore).

This alternation of generations is not always obligatory, for, in certain cases, the vegetative propagation of a gametophyte for example, may result in a life cycle in which there is a succession of gametophytic individuals before the formation of a sporophyte takes place. Moreover, in some remarkable cases, the alternation of generations is not connected with the alternation of the phases of the nucleus. Thus, in the phenomenon of **apogamy,** the vegetative budding of a gametophytic tissue may give rise to a sporophyte, while in the case of **apospory,** a gametophyte is produced from the sporophyte without the formation of any spore.

The chief advantage in the 'alternation of generations' is supposed to be that, the sporophyte by producing abundant spores helps in multiplication and dispersal, while the gametophyte by the production of gametes facilitates the merging of characters of different individuals. There are some disadvantages also; for example, in some mosses, the conditions for the fusion of gametes are often lacking, hence development of the sporophyte is practically impossible.

CHAPTER I

THALLOPHYTA—ALGAE

The thallophytes represent the oldest and the most primitive type of plants characterized by the simplicity of structure of their vegetative bodies and of reproductive method. In size, the thallophytees range from microscopic forms to macroscopic ones, often attaining a length of about 25-30 metres. Thallophytes are further characterized by the lack of differentiation of plant body into roots, stems and leaves; such an undifferentiated plant body is called a **thallus**. The thallus in the simplest case consists of a single cell, whereas the more complex forms are multicellular, which are either all alike or may show considerable differentiation of tissues. Some thallophytes develop stem-like, leaf-like and root-like organs, but their structures are very simple as compared to those in higher plants. Other characters which separate thallophytes from their allied groups are : (1) unicellular sex organs in the majority of cases, but when multicellular, all the cells form the gametes, *i.e.*, there is no jacket of sterile cells surrounding the gametes, as in the case of bryophytes and pteridophytes; (2) one-celled sporangia, but these are not so in the case of higher plants; and (3) the zygote never forms a multicellular embryo while still enclosed within the female sex organ.

The thallophytes reproduce in a variety of ways. The unicellular forms usually reproduce by the method of cell division, giving rise to two daughter cells, each of which is complete by itself and represents a distinct individual. When multicellular, specialized cells are often delimited for the purpose of reproduction. These specialized cells are in general known as **spores,** each of which is capable of giving rise to a new plant. The spores are produced within sacs to which the general term **sporangia** is applied. But these methods of reproduction are *asexual* in nature. They also reproduce *sexually*. The sexual reproductive units are known as **gametes,** which are naked protoplasts formed within specialized cells known as **gametangia.** When the gametes fuse, they give rise to bodies known as **zygotes** which develop into new plants. The gametic union may be a union of two gametes of equal size (**isogamy**), or by the union of two motile gametes of unequal sizes (**anisogamy**),

or by the union of a small motile and flagellate male gamete (**antherozoid** or **spermatozoid**), with a large, non-flagellate, passive female gamete (**oosphere** or **ovum**), the phenomenon being termed as **oogamy**. When the reproduction is oogamous, the gametangia are differentiated into **antheridium** (male) producing the **antherozoids** and **oogonium** (female) giving rise to oosphere or ovum or egg. The phenomenon of 'alternation of generations' has been definitely established in the thallophytes, though not well-marked in all cases.

The two main groups of thallophytes which stand out prominently are: the **Algae** and the **Fungi**, whose characters will be discussed in the following pages.

Differences between algae and fungi

(1) Algae possess the green colouring matter known as **chlorophyll**; Fungi, on the other hand, never possess chlorophyll. (2) Algae are **autophytes**, *i.e.*, they can prepare their own food from simple inorganic materials with the help of chlorophyll; Fungi are **heterophytes**, *i.e.*, they cannot prepare their own food, hence they must secure their food either directly or indirectly from other organisms and as such live as parasites or saprophytes. (3) Algae cannot live in darkness, as light is absolutely necessary for the preparation of their food; Fungi can live in light as well as in darkness. (4) The vegetative body in Algae is composed of parenchyma tissue; whereas the body of Fungi is composed of plectenchyma made up of fungal tissue. (5) The cellwalls of Algae are mainly composed of cellulose, but those of Fungi mostly of chitin or fungus cellulose.

The algae constitute an important group of thallophytes. They all possess chlorophyll and are, therefore, capable of manufacturing their own food. The chlorophyll, though invariably present, is not always pure green in colour, because the green colour is sometimes masked by the presence of other pigments, such as blue, golden brown, red, etc., and on this colour depends the classification of the group. The habitats of the algae are very diverse: some live in fresh water, some in brackish water, some are marine, some of them grow on rocks and walls or on barks of trees, while others live as **endophytes** within the tissues of certain higher plants. In a few cases, as in Lichens, the algae live in symbiotic association with fungi. The cellwall is usually composed of cellulose, and the reserve food materials are starch, oil and various other substances.

Origin of Algae and evolution among them

The origin of the various groups of present-day algae is supposed to have taken place from some unicellular non-flagellate aquatic protista. From this hypothetical ancestor there appeared the diverse groups polyphylectically. The oldest-known fossil records of algae that could have been traced so far, disclose the presence of some members of the Myxophyceae on the Proterozoic rocks. Cytologically also, excepting the bacteria, the class Myxophyceae, represents the most primitive group of living organisms, as no one member of this group possesses a well-organized nucleus, nor is there any trace of any other mode of reproduction other than the vegetative. With these facts in view, the Myxophyceae may be considered to have come first of all the algal lines. Some workers like Fritsch (1935), however, regard the Myxophyceae as the most reduced and consequently, the most advanced group among the algae.

Whatever might be the most primitive algal member, the class Chlorophyceae appears to have been derived from some *Chlamydomonas*-like flagellate unicellular ancestor. Each class of algae is characterized by the constancy in position of its flagella* in zoospores or gametes. From this hypothetical ancestral stock a progressive evolution took place in four different directions. One of these lines of development terminated in plants like *Volvox* having a motile colony. In another direction the colonies were non-motile, as in *Hydrodictyon* and *Pediastrum*. The third series gave rise to plant bodies with tubular or siphonaceous thalli, as may be found in *Vaucheria*. As a result of evolution in the last direction, there appeared multicellular filamentous forms, which were at first unbranched, as in *Ulothrix*, *Spirogyra*, *Zygnema*, and *Oedogonium*, and subsequently the branched ones, as in *Cladophora*, *Chaetophora*, *Draparnaldia*, *Draparnaldiopsis*, *Stigeoclonium*, *Bryopsis*, and others. It is believed that from some members of this filamentous line of Chlorophyceae the bryophytes originated.

Because of the fact that the Phaeophyceae possess motile reproductive cells, it is thought that the group has arisen from some flagellate unicellular brown algae, in a line parallel with the Chlorophyceae. It is of interest to note, however, that though the class

* There are two types of flagella generally met with in the different groups of algae : one is known as the *tinsel type*, while the other is referred to as the *whiplash type*. In the former case, the flagellum is provided with two rows of cilia or *mastigonenes*, while the latter one is without any such mastegonene.

has attained a very high degree of specialization in the body organization, it has not apparently been able to give rise to any higher category of plants.

The class Rhodophyceae is rather unique among the algae in several respects, and resembles no other algal class excepting the Myxophyceae. Members of both these two classes lack any type of motile flagellate cells. Further, the nature of pigments is also allied in them, for *phycocyanin* which is universally present in the Myxophyceae, is also found in some Rhodophyceae, and the phycoerythrin-like red pigment is also present in some blue-green algae. The red algae also represent a very ancient algal line, and its fossil records can be traced as far back as to the Ordovician. This group appears to have originated independently from some non-flagellate unicellular form. Some workers believe that the Ascomycetes, among the fungi, have originated from the Rhodophyceae.

Range of structure

The vegetative bodies in Algae in different classes show a gradual progression from simple to more complex forms and the whole range of structure may be grouped under the following heads :

(*a*) **Motile unicellular type.** The thallus is unicellular, more or less spherical or pear-shaped in form and flagellate. The flagella, two in number, are attached to the narrowed anterior end of the plant body. The nucleus occupies the middle region of the protoplast and the chromatophores, when present, either lie along the sides or occupy the posterior region of the cell. In certain cases, special rigid envelope with an aperture for the emergence of the flagella and separated from the cell proper by space can be seen. These forms are called *encapsuled* forms (*e.g.*, *Chrysococcus*). Sometimes the thalli are colourless due to absence of chromatophores.

(*b*) **Motile colony type.** In this group are to be found those forms in which the individual flagellate cells become aggregated together within a mucous envelope to form a spherical grouping or colony. The cells are all alike in form, complete in themselves and retain their motile character in the vegetative condition. The movement of the entire colony is brought about by the simultaneous activity of their flagella (*e.g.*, *Volvox*).

(c) **Palmelloid type.** In this type, during the vegetative phase, the individual cells are without flagella so that the motility disappears and the daughter cells produced by vegetative divisions remain embedded within a common gelatinous envelope, formed by gelatinization of the parent cellwall. This **'Palmelloid stage'** may be temporary, since sooner or later, the cells may develop flagella and resume active movement (*e.g.*, *Chlamydomonas*). It may also be of a permanent nature characterized by the loss of motility during the vegetative phase. In this case the reproductive cells are flagellate and motile (*e.g.*, *Tetraspora*).

(*d*) **Dendroid type.** This type of thallus is similar to that of the palmelloid type but the mucilage is produced locally, usually at the base of the cell (*e.g.*, *Prasinocladus*).

(*e*) **Coccoid type.** In this group the thalli are characterized by motionless unicellular individuals which become motile only during reproduction (*e.g.*, *Chlorococcus*). The power of dividing vegetatively is lost in this case and the reproduction takes place by the formation of zoospores.

(*f*) **Filamentous type.** The thalli are characterized by the type of cell division, called **vegetative division.** During the process, a parent protoplast ordinarily divides within the original cellwall and the two units of the protoplast are simply separated by the formation of a strip of membrane (septum) which is jointed laterally to the cellwall of the parent cell. Repeated vegetative division in one plane results in a filamentous thallus (*e.g.*, *Ulothrix*, *Spirogyra*, *Oedogonium*, etc.). If the septa are formed along two planes and at right angles to one another, a flattened leaf-like thallus develops (*e.g.*, *Ulva*). The branching habit in a filamentous thallus is obtained due to formation of lateral outgrowths of more or less numerous cells and in which septa-formation takes place in transverse plane as in the main axis (*e.g.*, *Cladaphora* and many other Chlorophyceae).

(*g*) **Heterotrichous type.** This type represents the most highly evolved filamentous plant body. The thallus is characterized by having two distinct well-differentiated parts, namely, (*i*) a prostrate creeping system of the branching filaments which are attached to the substratum, and (*ii*) an erect system consisting of one or more branched filaments that trail out in water (*e.g.*, *Chaetophora*, *Draparnaldiopsis*, *Bryopsis*, *Batrachospermum*, etc.).

(h) **Siphonaceous type.** This group is characterized by considerable extense of the thalli without any septation. Thus, a large multinucleate **coenocytic** structure originates (e.g., *Vaucheria*, *Botrydium*, etc.).

(i) **Complex type.** In this group the thalli range from more or less compact pseudo-parenchymatous bodies to true parenchymatous bodies of well-differentiated macroscopic forms as evidenced in Phaeophyceae and Rhodophyceae.

Reproduction

The various methods of reproduction in Algae can be grouped under the following categories.

Vegetative. In unicellular forms, it takes place by cell divisions and the daughter cells, thus produced, function as new individuals. In colonial forms, two individual colonies may arise by mere splitting of the mature colony (*e.g.*, Volvocales). In filamentous types, vegetative reproduction takes place by fragmentation of the threads and each broken part gives rise to a new individual. Vegetative reproduction is found in various classes of Algae and is the characteristic feature of the Myxophyceae* where complex specialized structures are to be found.

Asexual. This is the commonest method of reproduction in which spores, one (*e.g.*, *Oedogonium*) to several hundred (*e.g.*, *Cladophora*), are formed within specialized cells, called **sporangia** which may not be morphologically different from the vegetative cells. The spores may be naked, motile and with two to four flagella (**zoospores**), or may be non-motile (**aplanospores**). The aplanospores are modified zoospores which have lost their power of movement and each is surrounded by a definite wall which is distinct from the parent cellwall. An aplanospore with greatly thickened wall is a **hypnospore.** The zoospores resemble morphologically the unicellular members of the Volvocales and from the standpoint of phylogeny they show reversion to primitive ancestral flagellate condition.

Sexual. This type of reproduction is characterized by the fusion of two gametes and its different methods are as follows :

(*a*) **Isogamy.** In this case two gametes of the same morphological indentity, flagellate or non-flagellate, fuse to form **zygote.**

*Discussed in detail under Myxophyceae.

Majority of isogamous Algae are dioecious, since the fusing gametes come from different individuals of opposite strains.

(*b*) **Anisogamy.** It is a case of modified isogamy and the fusing flagellate gametes show slight difference in their behaviour, one being more passive than the other (*e.g.*, Chlamydomonadaceae). In some cases the fusing gametes are unequal in size. This is known as **heterogamy.**

(*c*) **Oogamy.** This type of reproduction represents the highest stage in the series. Here, a large motionless, non-flagellate female gamete, called **oosphere** or **egg,** is fertilized by a much smaller flagellate, active male gamete, called **antherozoid** (*e.g.*, Volvocales, Ectocarpales). Both types of gametes may be produced on the same (*monoecism*) or different individuals (*dioecism*). Usually, the oosphere or egg is retained within the female sex organ, the **oogonium,** where it receives the male gamete. It is, therefore, a receiving cell. The male gametes, produced within the male sex organ, the **antheridium,** are ultimately discharged and one or more of them enter the oogonium, through an aperture on its wall. In Rhodophyceae the oogamous reproduction is of a specialized type. The male gametes are non-flagellate, therefore, non-motile and passively carried to the female sex organ by water current.

Life cycles

The type of life cycles in Algae can be conveniently grouped into two broad categories, namely, (1) an alternation of haploid generations, in which a diploid generation is absent, and (2) an alternation of distinct haploid and diploid generations.

Those forms in which regular alternating haploid and diploid generations are absent can be divided into two groups : (*a*) the oogonium is haploid and (*b*) the oogonium is diploid. In the former case, the vegetative body of the plant is a gametophyte. The diploid phase, resulting from the sexual union, is restricted only to the zygote. The diploid nucleus of the zygote, at the time of germination, undergoes meiosis producing four haploid nuclei, from which usually four asexual reproductive units are formed, each of which is capable of producing a new haploid plant. This type of life cycle may be found in the majority of Chlorophyceae and possibly in all Xanthophyceae and Chrysophyceae. In case, where the oogonium is diploid, the vegetative body of the alga is a sporophyte and is evidently in the diploid condition.

Meiosis takes place during the formation of gametes which represent only the haploid phase. These gametes soon fuse in pairs to form diploid zygotes, each of which is capable of giving rise to a new diploid plant. This type of life cycle can be met with in some members of Siphonales and all Bacillariophyceae.

The cases where an alternation of haploid and diploid generations takes place can be grouped under the following categories :

(*a*) **Isomorphic alternation**. This type is characterized by the presence of two individuals which are morphologically identical, but one of them is haploid (gametophyte) producing gametes and the other is diploid (sporophyte) producing spores. Meiosis takes place in the diploid generation, during the formation of spores, and each of the spores on germination produces a haploid generation. Gametes, formed from this haploid generation, unite and give rise to the diploid generation, as found in some Chlorophyceae (*e.g.*, Cladophorales, Ulvaceae), Phaeophyceae (*e.g.*, Dictyotales, Cutleriales) and a number of Rhodophyceae. Some members of the Rhodophyceae are very peculiar in that they are **diplobiontic,** in which diploid generations alternate with a haploid one.

(*b*) **Heteromorphic alternation.** This type of life cycle is characterized by an alternation of haploid and diploid generations which are morphologically dissimilar. Usually, the diploid plant (sporophyte) is much larger than the small, few-celled, haploid individual (gametophyte), as can be found in some members of Ectocarpales, Laminariales, etc. This type of alternation is quite similar to that found in higher cryptogamic plants (*e.g.*, ferns and their allies).

Classification

The Algae are broadly classified by Fritsch† into eleven Classes, namely, I. *Chlorophyceae*, II. *Xanthophyceae*, III. *Chrysophyceae**, IV. *Bacillariophyceae*, V. *Cryptophyceae**, VI. *Dinophyceae**, VII. *Chloromonadineae**, VIII. *Eugleninae**, IX. *Phaeophyceae*, X. *Rhodophyceae*, and XI. *Myxophyceae*.

The characterization of some of the Classes with a brief account of a few of the chief members belonging to each has been discussed in the following pages.

†Fritsch, F. E. (1935). The Structure and Reproduction of Algae.
*Not treated in this book.

CLASS I. CHLOROPHYCEAE

Salient features

The Chlorophyceae, or the green algae, are characterized in having grass-green-coloured chloroplasts containing the photosynthetic pigments, chlorophyll *a*, chlorophyll *b*, carotenes and xanthophylls, of which the first two predominate over the others. There are several xanthophylls in the chloroplasts which are not found in other algae, and of these, *lutin* is found in abundance. Food reserves are stored in the form of starch, whose formation is intimately associated with pyrenoids. Motile reproductive bodies, zoospores and gametes, are usually associated with two or four whip-like flagella of equal length.

General characters

The members of this group are found both in fresh and salt waters. The majority of them occur as submerged, freshwater plants being attached to submerged rocks, wood-pieces and similar other objects, but may also float on the surface of stagnant water forming green scums. Quite a large number of species grow on moist soil, rocks and cliffs, damp wood-work, barks of trees and even on snow and ice. A few species are internal parasites on land plants, or may occur as epiphytes upon land animals.

In general, the members of Chlorophyceae show great variations in form and structure of their vegetative body, ranging from simple unicellular types to typical multicellular filaments through intermediate colonial forms. When multicellular, the number of cells may be definite or indefinite. But when indefinite, the cells of the thallus may be arranged in irregular masses, in filaments, in sheets, or in solid or hollow cylinders. The unicellular forms may be non-motile or motile by flagella. Typically, the plant body is filamentous and it occupies a prominent place among most of the Orders of the green algae.

With the exception of a few primitive unicellular genera, the protoplast of Chlorophyceae is surrounded by a distinct cell wall which often becomes considerably thick. The cell wall consists of at least two concentric portions: (*a*) an inner homogeneous or concentrically stratified layer, mostly or wholly made up of cellulose, and (*b*) an outer pectose layer which in some genera may be chitinized or impregnated with lime.

The protoplast is well-differentiated into cytoplasm, nuclei and chloroplasts. It mostly occurs as the primordial utricle surrounding a conspicuous central vacuole. But, in some cases, several vacuoles may be present instead. When the cells are flagellate, as in the unicellular and some of the colonial forms, there are usually two

small **contractile vacuoles** near the base of the flagella. They contract alternately and are regarded as excretory organs. In some cases, the sap of the vacuole becomes coloured due to anthocyanin. There may be one or more nuclei in each protoplast, and these are found either in the primordial utricle or are suspended in a mass of cytoplasm at the centre of the vacuole by means of cytoplasmic threads. The nucleus possesses a distinct nuclear membrane, one or more nucleoli and a characteristic chromatin reticulum. The nuclear division is mitotic. The chloroplasts are most characteristic and are of various forms. They may be cup-shaped, laminate, entire or perforate, disciform, peripheral in position, and are mostly with one or more pyrenoids. Each pyrenoid has a central proteinaceous portion which is surrounded by plates of starch. The food reserves are usually in the form of starch, but fats and oils are found in some cases.

Within the chloroplasts the photosynthetic (chlorophyll *a* and chlorophyll *b*) and other pigments (carotenes: α-carotene and β-carotene; xanthophylls: lutin, zeaxanthine, viola-xanthine and neoxanthine) become associated together, but the chlorophylls predominate over the others. The amount of the pigment also varies from species to species, and according to their proportions, typically grass-green to almost light-green Chlorophyceae are found in nature. In some genera, the vegetative cells and the zygotes also contain a red pigment, **haematochrome,** which masks other pigments. Haematochrome is a carotenoid pigment. Sometimes the colour of the cells in certain species is modified by the presence of **anthocyanin** pigments of the cell sap.

The motile vegetative and reproductive cells are provided with flagella inserted at the anterior end of the cell. They are usually of equal length. Located near the insertion of the flagella there is an orange-red to reddish brown circular or oval spot, called the **eyespot** or **stigma,** which is regarded as a photo-receptive organelle and is supposed to control the directive movement of the flagella.

Reproduction

The methods of reproduction in green algae are well-advanced and show great variations. All the three principal methods of reproduction, as detailed below, are found in this group.

Vegetative reproduction takes place usually by the process of fragmentation. Among filamentous forms, fragmentation is

either due to accidental breaking of a filament or certain cells of the filament may produce spores or gametes, so that short sections of the filament become ultimately separated from one another resulting in the increase of the number of filaments. The colonial genera reproduce vegetatively by accidental fragmentation of the colony. Among unicellular forms, vegetative reproduction always takes place by cell division, which, in multicellular forms, becomes a method for the growth of the thallus.

Asexual reproduction usually takes place by the production of spores within metamorphozed vegetative cells. The spores may vary in number, from one to many in each cell and may be either naked and motile or provided with a distinct wall. The motile spores are known as **zoospores,** which are provided with two, four or more flagella of equal length at the anterior end. The liberation of zoospores usually takes place by the formation of a pore in the wall of the mother cell, or by the breaking or gelatinization of the sporangial wall. The non-motile spores are known as **aplanospores,** whose walls are quite distinct from the wall of the mother cell. These are in reality modified zoospores which have secreted wall around them prior to the liberation from the mother cell. The aplanospores are liberated by the rupture or decay of the wall of the mother cell. The mother cell producing these spores is termed a **sporangium,** which, in most cases, is not morphologically different from the vegetative cells. Sometimes, the wall of the aplanospore becomes greatly thickened and forms a **hypnospore.** Asexual reproduction also takes place by the formation of **akinetes.**

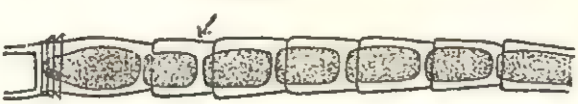


Fig. 12. Formation of akinete in Chlorophyceae.

In such cases, a single non-motile spore is formed within the sporangium whose wall is not distinct from that of the spore. But, the vegetative cells often become very much thick-walled containing abundant food reserve to form akinete-like structures for tiding the alga over unfavourable periods.

The sexual reproduction in Chlorophyceae ranges in complexity from the simplest to the most complex sex structures.

The methods of gametic union may be arranged in an evolutionary series, and are noticeable from the most primitive to the most highly advanced forms with specialized and differentiated sex structures.

In the simplest case, sexual union is by **isogamy,** *i.e.*, gametic union takes place between morphologically identical flagellate or non-flagellate gametes. *Ulothrix* is a familiar example in which there is a fusion of a flagellate gamete with another gamete of identical size and structure. This is known as **planogamic union.** Sometimes (as in *Spirogyra*, *Zygnema*, etc.) there is union of gametes without flagella, and this type of isogamy is known as **aplanogamy.** In some cases, the plant reproduces by **anisogamy,** in which gametic union is effected between two flagellate gametes of unequal sizes, as in *Caulerpa*. The most advanced method of reproduction is **oogamy.** In this case, gametic union takes place between a small flagellate, motile, active male gamete and a large non-flagellate, non-motile, passive female gamete as in *Vaucheria*, *Oedogonium*, etc. The male gametangium producing the antherozoids is known as the **antheridium,** and is usually a distinct structure easily recognizable from the vegetative cells. Each antheridium produces one or more antherozoids. In most cases the oosphere or egg is produced singly within the female gametangium, known as the **oogonium,** which differs morphologically from the vegetative cells. The **zygote** formed as a result of sexual union, usually after a period of rest, gives rise to one or more new plants. Many species of Chlorophyceae are **homothallic,** *i.e.*, **monoecious.** In such cases, gametes derived from a single parent plant unite in pairs. Other species are **heterothallic,** *i.e.*, **dioecious.** Here gametes of different parentage fuse in pairs.

There are various instances in which **parthenospores** (or **azygospores** or **aboospores** or **azygotes**) are formed directly from the gametes in the absence of sexual union.

Classification

The Chlorophyceae are divided into nine Orders (Fritsch, 1935*) which may be distinguished as follows :

1. **Volvocales**:—Unicellular or colonial; motile throughout life or form sedentary colonies which readily revert to a motile condition; reproduce asexually as well as sexually ; mainly

*Fritsch, F. E. (1935). The Structure and Reproduction of Algae.

freshwater. Examples—*Chlamydomonas*, *Sphaerella*, *Pandorina*, *Eudorina*, *Volvox*, etc.

2. **Chlorococcales**:—Unicellular or colonial; non-motile in the vegetative condition: reproduce by zoospores or aplanospores; almost exclusively freshwater. Examples—*Hydrodictyon*, *Pediastrum*, etc.

3. **Ulotrichales**:—Filamentous, simple and unbranched or cellular expanse with small cells; chloroplasts parietal, axial or stellate; sometimes filaments simple and with large multinucleate cells; mostly isogamous; most species freshwater, some are marine. Example—*Ulothrix*, *Ulva*, *Enteromorpha*, etc.

4. **Cladophorales**:—Simple or branched, filamentous with cells containing two to many nuclei and usually with elaborate large chloroplasts; mostly isogamous; freshwater and marine. Example—*Cladophora*.

5. **Chaetophorales**:—Filamentous and sharply differentiated into prostrate and erect portions (**heterotrichous**); erect portion often reduced and the prostrate portion often forming discoid expanse; hairs of diverse types are often present; mostly isogamous and freshwater. Examples—*Chaetophora*, *Enteromorpha*, *Draparnaldiopsis*, *Trentepohlia*, *Coleochaete*, *Protococcus*, etc.

6. **Oedogoniales**:—Simple or branched, filamentous; zoospores multiflagellate; oogamous; cell divisions characterized by intercalation of strips of membrane between two parts of the mother cell; entirely freshwater. Example—*Oedogonium*.

7. **Conjugales**:—Unicellular or colonial (generally filamentous) with elaborate chloroplasts; motile gametes unknown; reproduction by vegetative cell division or by conjugation of amoeboid gametes; exclusively freshwater. Examples—*Spirogyra*, *Zygnema*, *Cosmarium*, *Closterium*, etc.

8. **Siphonales**:—Filamentous; without septa or elaborately differentiated; all parts coenocytic; chloroplasts numerous and discoid; sexual reproduction mainly isogamous, sometimes oogamous, unknown in many cases; mostly marine. Examples—*Vaucheria*, *Caulerpa*, *Bryopsis*, etc.

9. **Charales**:—Thallus well-differentiated into nodes and internodes; internodes sometimes corticated; branches of limited growth in whorls; chloroplasts numerous and discoid; cells usually uninucleate; reproduction vegetative and sexual with elaborate oogonia

and antheridia; germination of zygote indirect; freshwater and brackish water. Examples—*Chara*, *Nitella*, etc.

Alternation of generations

Some Chlorophyceae show regular alternation of similar haploid and diploid generations, but in great majority the plant body is haploid with the zygote representing the only diploid phase. In the simplest case, as illustrated by *Chlamydomonas*, the life cycle consists of alternation of unicellular haploid and diploid phases. This alternation is, however, not obligatory in the sense that the haploid phase will always give rise to the diploid phase, because there may be a formation of haploid individuals in succession before the formation of a diploid phase. On the contrary, it is obligatory in the sense that the diploid phase always gives rise to a haploid one. This represents, therefore, the most primitive type of life cycle. Starting from this primitive condition, one finds an evolution of multicellular thalli in either phases (haploid, as in *Spirogyra*, *Oedogonium*, etc., or diploid, as in *Codium*) of the life cycle. In such cases, there is an alternation of a multicellular haploid generation with a unicellular diploid phase, or a multicellular diploid generation with a unicellular haploid phase. Lastly, there may be an alternation between multicellular haploid and diploid generations (as in Cladophoraceae, Ulvaceae, Chaetophoraceae). The two generations may be quite identical (**isomorphic**) with each other, or they are morphologically different (**heteromorphic**).

ORDER 1. VOLVOCALES

Unicellular or colonial; motile throughout life or form sedentary colonies which readily revert to a motile condition; reproduce asexually as well as sexually; mainly freshwater.

CHLAMYDOMONAS

(Fam. CHLAMYDOMONADACEAE)

Chlamydomonas is a widely distributed free-swimming, green alga which inhabits stagnant water or damp soils.

The common Indian species of *Chlamydomonas* are *C. atactogama*, *C. gloesgama*, *C. intermedia* and *C. reinpardi*.

Vegetative body

The plant body is unicellular and the cells are either spherical, ellipsoidal or pyriform (pear-shaped). The protoplast is surrounded by a definite layer of cellulose wall, and in some cases an additional external gelatinous sheath may be present. Each cell is provided with two **flagella,** which are inserted at its anterior end and are very close to each other. In some cases, the cell wall is provided with a distinct papilla at the anterior end. The major portion of the protoplast is usually occupied by a single, massive, cup-shaped chloroplast. There is a single nucleus which is, in most cases, embedded in a colourless cytoplasm filling the cup. Sometimes the chloroplast may be star-shaped or laminate in form. Usually, a single pyrenoid is present in each chloroplast, but in some cases two or more pyrenoids may be present, or they may be totally absent. Typically, there are two **contractile vacuoles** at the anterior end of the protoplast occupying the bases of the flagella, but the number and position of these vacuoles may vary in different species. There is a photo-receptive organ, the **'eyespot',** which lies at the anterior end and is supposed to be concerned in directing the movement of the flagella.

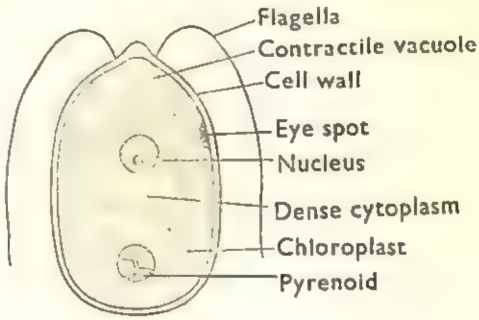


Fig. 13. *Chlamydomonas*. A vegetative cell.

Reproduction

Chlamydomonas reproduces both asexually and sexually.

During asexual reproduction the protoplast of each vegetative cell divides longitudinally into two protoplasts, which again divide and re-divide forming 4 or 8 daughter protoplasts. Each daughter protoplast then secretes a wall around it and develops a pair of flagella at its anterior end. The cell wall of the parent cell ruptures or undergoes gelatinization and thereby the daughter cells are liberated.

Very rarely the protoplast of a vegetative cell contracts, rounds up and forms an **aplanospore** after secreting a wall of its own.

When *Chlamydomonas* grows on damp soil, the daughter cells formed by the successive divisions of the protoplast do not develop their flagella but remain embedded in a common gelatinous matrix, formed by the gelatinization of the cell wall of the parent cell. This is usually followed by division and re-division of the daughter cells by the subsequent gelatinization of their walls forming colonies consisting of hundreds of cells embedded in a common matrix. This is known as the **"palmella stage"** resembling the genus *Palmella*, a green alga forming amorphous colonies. If these colonies be flooded with water, each daughter cell may develop its flagella and may swim away from the colony. Sometimes these daughter cells may develop into resting spores, called **akinetes.**

Most species of *Chlamydomonas* reproduce sexually by conjugation. The method of formation of gametes is similar to the

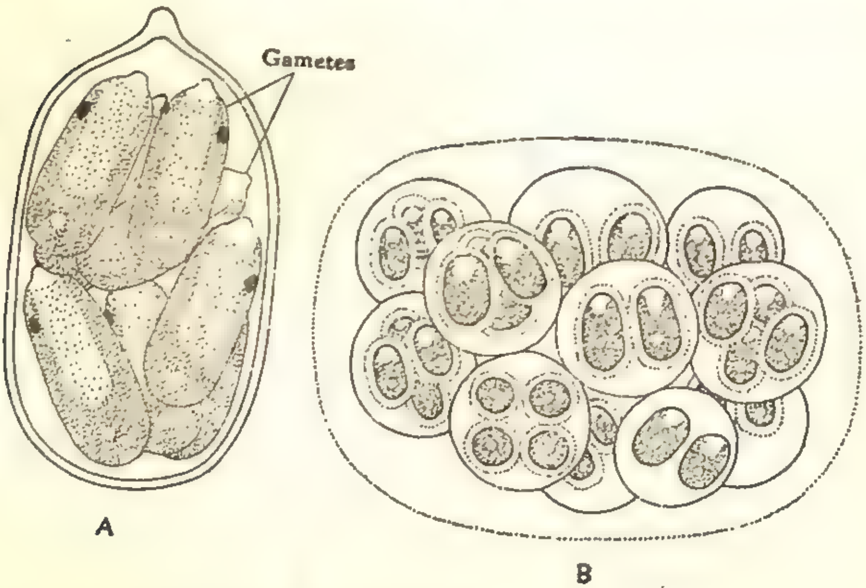


Fig. 14. *Chlamydomonas*.
A, Formation of gametes within the parent cell;
B, Palmella stage.

formation of the daughter cells from a vegetative protoplast as already stated. But in this case, the number of daughter cells may be 8, 16 or 32, and they are usually naked, biflagellate protoplasts; when walled, the protoplast of each gamete leaves its original wall

before union. Union may take place between the gametes derived from the same cell (**homothallic**), or between gametes derived from different cells (**heterothallic**). The fusing gametes may be morphologically alike (**isogametes**), or rarely one may be larger than the other (**anisogametes**). During fusion both the gametes are usually active, but in some cases one may be passive. After union of the gametes the flagella either disappear or may persist for the time being so that the resulting quadriflagellate **zygote** remains motile for sometime. Finally, it comes to rest and secretes a wall around it. The wall of the zygote is thick and shows surface reticulations, or may bear spiny projections. Before germination the diploid nucleus of the zygote undergoes reduction division, typically forming four haploid nuclei, of which three may degenerate. By cleavage process uninucleate protoplasts are formed following reduction division and each protoplast is metamorphozed into a biflagellate daughter cell. These cells are finally liberated by the rupture of the zygote wall.

SPHAERELLA

(Fam. CHLAMYDOMONADACEAE)

Sphaerella is a freshwater alga found in ponds and pools. This alga is also known by the name *Haematococcus*, since it contains a red-coloured carotenoid pigment, **haematochrome,** which has a masking effect on the chlorophyll. One species, called *S. nivalis*, occurring on the snows in the Arctic and Alpine regions, contains such an abundance of haematochrome in the resting cells that it appears as blood-red patches wherever it grows.

The common Indian species of *Sphaerella* is *S. lacustris*.

Vegetative body

The plant body is unicellular and resembles that of *Chlamydomonas* to a great extent, from which it differs mainly in having its protoplast separated from the cell wall. The thin cellulose wall is separated from the protoplast by an inner wall, which is thick and mucilagenous, and pierced by a number of delicate cytoplasmic strands (**pseudopodia**). The large hemispherical, hollow solitary chloroplast lies embedded in the cytoplasm. The nucleus lies in the central region of the colourless cytoplasm. There are a number of pyrenoids, numerous irregularly scattered contractile

vacuoles, and an eyespot. The haematochrome granules are also numerous, on whose relative proportion depends the colour of a particular cell. At the anterior end there are two long flagella. By withdrawing these flagella the alga generally forms a **cyst,** and in this encysted condition it is commonly found.

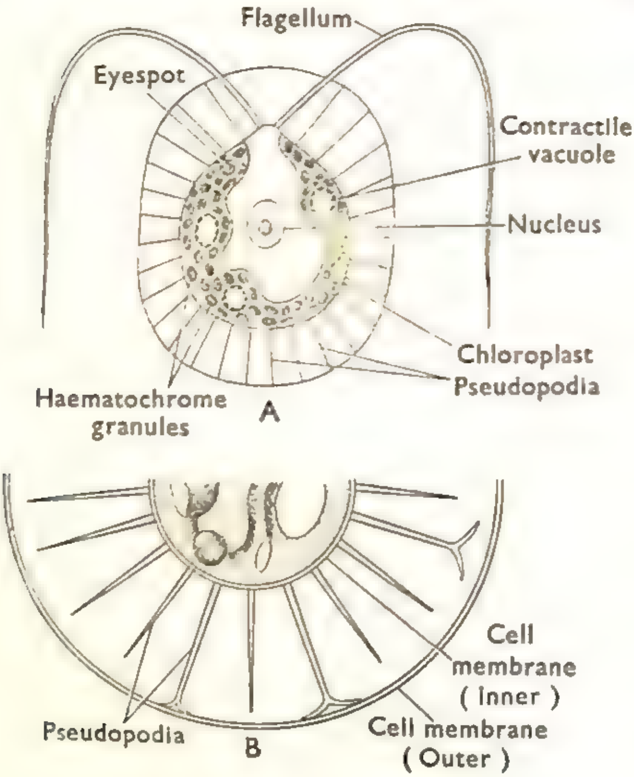


Fig. 15. *Sphaerella.*
A, The plant body; B, A portion of the same (magnified).

Reproduction

Sphaerella reproduces both asexually and sexually.

During asexual reproduction longitudinal division of the protoplast of the motile cell takes place, but typical zoospores are not formed. These blocks of protoplast finally come out of the mother cell, and each one develops into a new *Sphaerella* plant.

The protoplasmic contents of an encysted cell sometimes undergo repeated divisions thereby giving rise to the *palmella stage*. These resting cells produce minute, motile gametes, which unite in pairs to give rise to the zygote. As in *Chlamydomonas*, by the reduction division of the zygote nucleus and subsequent cleavages, uninucleate protoplasts are formed. These blocks are ultimately converted into biflagellate cells which finally get liberated by the rupture of the zygote wall.

PANDORINA

(Fam. CHLAMYDOMONADACEAE)

Pandorina is a widely distributed freshwater alga.

The common Indian species of *Pandorina* is *P. morum.*

Vegetative body

The plant body is a free-swimming **coenobium,** *i.e.*, a colony of a definite number of cells, arranged in a specific manner. The hollow, spherical coenobium is made up of four to thirty-two biflagellate cells, lying closely fitted together and embedded with in a mucilagenous matrix of homogeneous consistency. In some cases, an additional watery outer sheath may be present. The cells in a colony are generally so closely pressed that they become laterally flattened, exception being found in one species. A vegetative cell is usually pear-shaped with a prominent, cup-shaped chloroplast containing one to several pyrenoids and a single nucleus. At the anterior end of the cell there is a prominent eyespot and two flagella. At the base of the flagella two contractile vacuoles are always present.

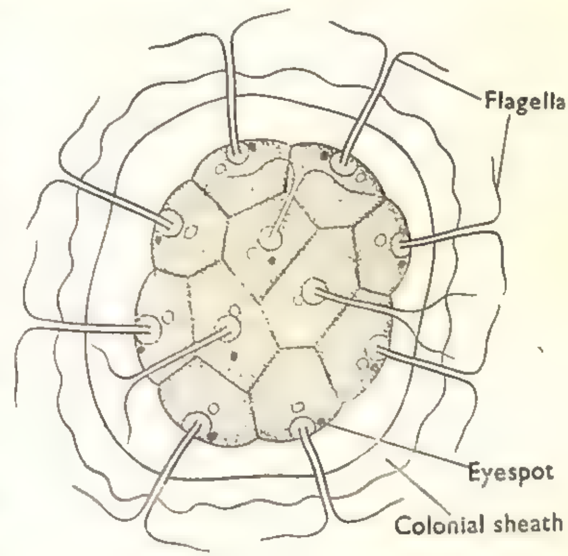


Fig. 16. *Pandorina.*

Reproduction

Pandorina reproduces both asexually and sexually.

Before asexual reproduction a colony stops its movement, becomes inactive, and sinks to the bottom of water. Its sheath becomes more watery in nature and swells up considerably. Each individual cell of the coenobium undergoes simultaneous longitudinal division to form a daughter coenobium of sixteen or thirty-two cells. After the first three divisions, the cells are cruciately disposed, and a typical eight-celled curved plate or **plakea** is formed. Further division stops either at the sixteen-celled or thirty-two-celled stage. Though not recorded properly, yet it is generally

presumed that inversion takes place in a developing young coenobium. These daughter colonies then come out of the envelope of the parent colony and swim away.

The sexual reproduction is anisogamous, in which two biflagellate gametes of unequal sizes unite together. The larger of the two is the female gamete, which is usually less active than the smaller one, the male gamete.

Divisions of the protoplast for the formation of gametes take place in exactly the same way as those occurring during asexual reproduction. The groups of daughter cells, which are to act as

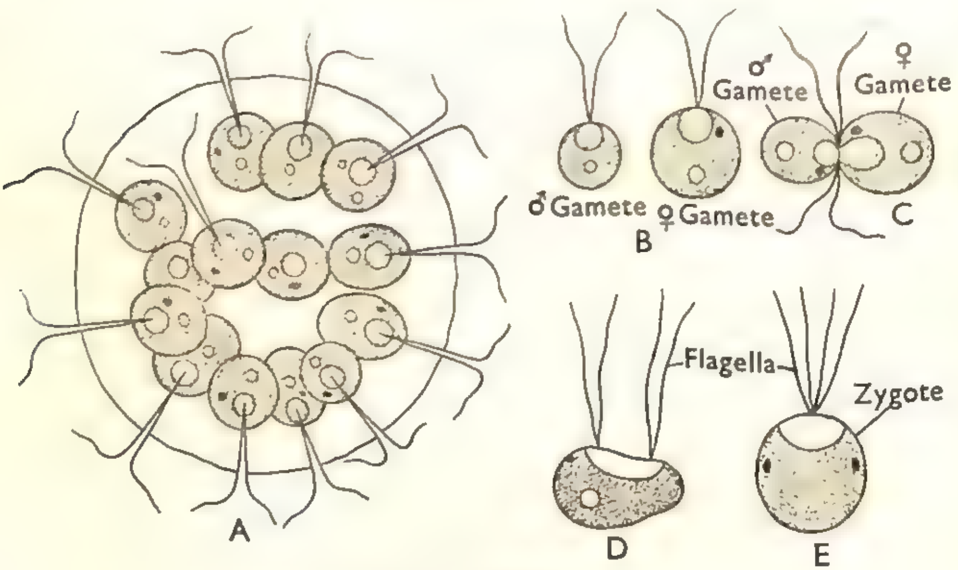


Fig. 17. *Pandorina*.
A, A female colony; B, The two types of gametes; C, Union of gametes; D—E, Zygotes in different stages of development.

gametes later, at first swim in water as colony-like units enclosed within broad watery envelopes. Finally, the gametes escape out of the common sheath, swim freely and ultimately unite in pairs. The fusion may be either terminal or lateral, and as a result, a quadriflagellate zygote is produced. The zygote swims for a very short period, after which the flagella are lost and a wall is secreted all around it. The protoplast of an old zygote is red-coloured due to the presence of haematochrome. After some time, the zygote germinates; a vesicle is formed and the entire irregularly green and orange protoplast is extruded into it. Very soon the protoplast

develops two flagella and thus a **zoospore** is developed, which then swims away. In some cases, two to three such zoospores may be formed from a single zygote. After swimming for some time, the zoospore comes to rest, withdraws its flagella, secretes a gelatinous sheath, and undergoes several divisions giving rise to a typical *Pandorina* colony.

EUDORINA

(Fam. CHLAMYDOMONADACEAE)

Eudorina is widely distributed in freshwater lakes, ponds and ditches as well as in small puddles. It is found as a plankton, particularly in the autumn.

The common Indian species of *Eudorina* are *E. elegans*, *E. indica* and *E. illinoisensis*.

Vegetative body

The vegetative body of *Eudorina* is a globose, or obovoid, or ellipsoid coenobium of sixteen to sixty-four cells. The latter types of coenobia usually have several lamillate projections, developed at their posterior pole. The colony, however, is usually made up of thirty-two cells, arranged in five distinct transverse tiers; each of the anterior and posterior tiers contains four cells, while in each of the three medium ones there are eight cells present. The colonial envelope is homogeneous. Each individual cell is globose, and is of the usual *Chlamydomonas* structure, but the number of pyrenoids varies from one to several, according to the species. The eyespot is solitary as usual, but in some species it progressively diminishes in size from the anterior to the posterior tiers of the colony, and may even be completely wanting in the cells of the lowermost tier. The different cells are interconnected by extremely delicate cytoplasmic strands, which become visible after suitable staining only.

Reproduction

Eudorina reproduces both asexually and sexually.

Asexual reproduction takes place in the same way as in *Pandorina* by all the cells of a colony usually dividing to give rise to daughter colonies. Occasionally, however, one or a few cells in the colony do not undergo any division at all. As a result of continued cell division, a plakea is formed. It is at first curved, later on

becomes flat, and finally curves again in the reverse direction; the corners ultimately meet together, and thus a hollow coenobium is produced. As in *Pandorina*, the new daughter colonies come directly out of the parent colony, and swim away.

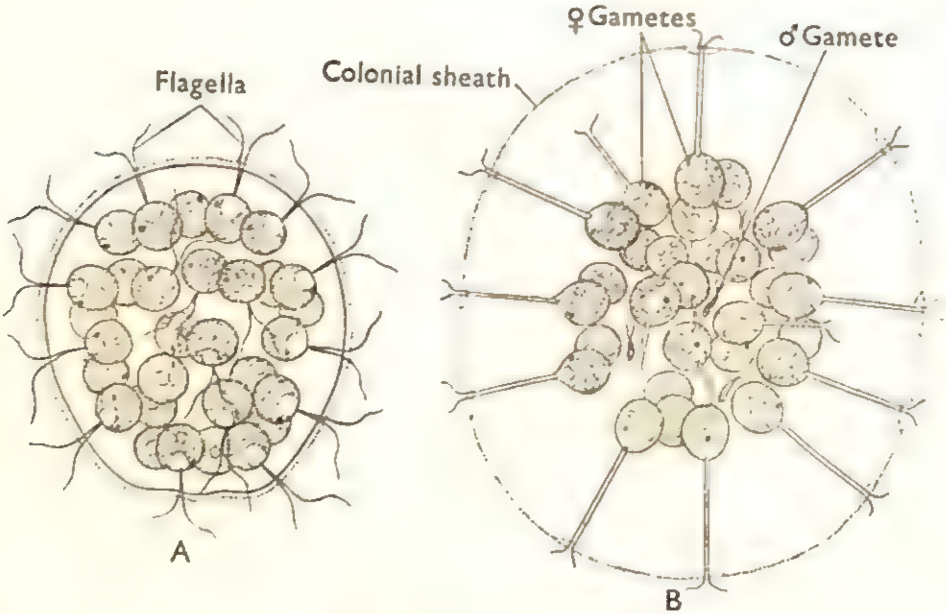


Fig. 18. *Eudorina*.
A, A colony; B, Two types of gametes enclosed within the colonial sheath.

On account of gradual desiccation, a *palmella stage* may be developed from a vegetative colony. But as soon as sufficient water is available, the palmelloid cells once again develop flagella, and come out as independent **zoospores,** each of which may give rise to a typical *Eudorina* colony in course of a few hours only. Sometimes the cells of a colony lose their flagella, and are converted into akinetes.

The sexual reproduction in *Eudorina*, though of the anisogamous type, is of a very advanced nature, and is almost oogamous. The gametes are very much dissimilar as regards their shape and size. Further, the female gametes are never free-swimming and get fertilized *in situ*. The colonies are homothallic or heterothallic. In the former, usually the four anterior cells give rise to the male gametes, and the rest behaving as the female ones. The cells producing the male gametes divide in the same manner as in the case of asexual reproduction. Each cell finally produces a

curved plakea of sixty-four fusiform, biflagellate male gametes. In heterothallic species, the male gametes escape from the old envelope in bunches, and swim as individual units. When a bunch comes in the neighbourhood of a female colony, the individual gametes are set free. In both homothallic and heterothallic species the ordinary vegetative cells are directly converted into female gametes without any serious change. The swimming male gametes enter straight through the enveloping matrix of a female colony, and ultimately coming in contact with the female gametes fuse with them. A zygote, produced as a result of such a fusion, is smooth-walled and its protoplast is deeply red-coloured due to presence of haematochrome. It remains confined inside the female colony till liberation by disintegration of the colonial sheath. At the time of germination, a vesicle-like structure is formed on one side of the wall, which is somewhat swollen by this time. Inside the vesicle there usually lies one red-coloured zoospore and two or three minute colourless bodies, which may be the disintegrating zoospores. Finally, the zoospore escapes from the vesicle, swims for sometime in water, and ultimately undergoes several divisions to produce a new colony.

VOLVOX

(Fam. VOLVOCACEAE)

Volvox is a freshwater green alga which occurs abundantly in tanks, pools, etc.

The common Indian species of *Volvox* are *V. globator*, *V. aureus*, *V. africanus*, *V. prolificus*, etc.

Vegetative body

The plant is a free-swimming coenobium. The coenobium is hollow, spherical or ovoid, appears in nature as large as a pinhead, and is composed of thousands of cells arranged in a layer joined to one another by a mucous sheath. Each cell has got a cellulose wall and a thick mucous sheath. It is more or less oval in shape, and has (1) a central nucleus, (2) one cup-shaped or stellate chloroplast with one or more pyrenoids, at the posterior end, (3) two equal flagella at the anterior end, directed towards the surface of the coenobium, (4) 2-6, often scattered, contractile vacuoles,

and (5) an eyespot, in the form of a reddish or brownish dot at the anterior end. The eyespot is a photo-receptive organ, intimately concerned with directing the movement of the flagella. Contractile vacuoles alternately expand and contract, and probably serve as excretory organs. It is due to the movement of these flagella of all the cells that the colony moves in water.

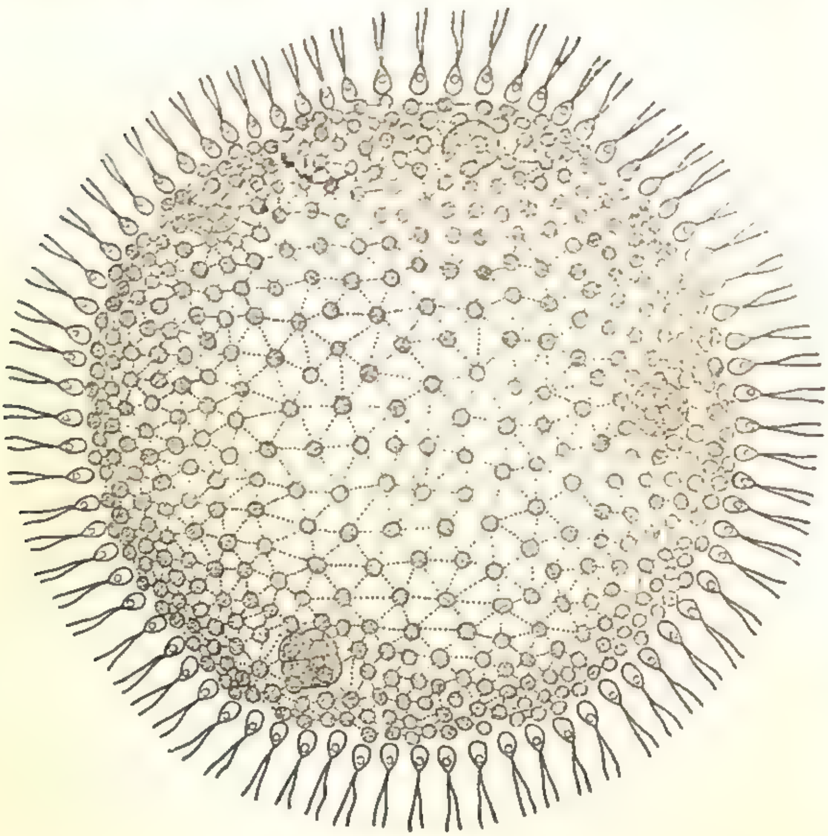


Fig. 19. *Volvox.*
A mature colony with young colonies inside.

Reproduction

Reproduction is asexual at the beginning of the growing season and sexual at the end.

A colony develops usually from 4-10 asexual reproductive cells, called **gonidia,** which become many times larger than the ordinary cells, lose their flagella and lie within the globular mucilage sac that projects towards the interior of the colony. Each of them, by

repeated divisions, gives rise to a spherical group of cells and forms a daughter colony, which swims about in the cavity of the parent colony. The daughter colonies are ultimately liberated due to rupture or decay of the mother colony.

During the formation of daughter colonies, the plakea undergoes an inversion just as in *Eudorina.*

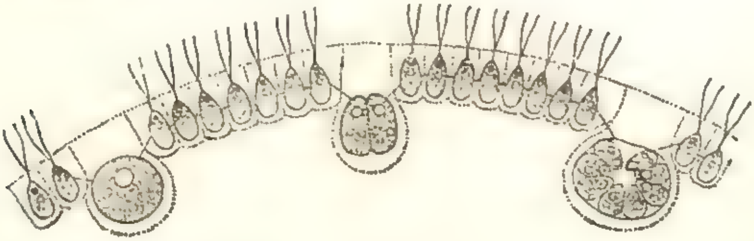


Fig. 20. *Volvox.*
Formation of daughter colony in the rim of mature colony which has lost its flagella and started to form a new colony.

The sexual reproduction is **oogamous** due to the fusion of a motile antherozoid with a non-motile egg. Though the gametes may be formed in any cell of the colony, the gamete-formation is usually restricted to certain cells only. Oogonia and antheridia are highly enlarged cells within a mucous sheath. The oogonium con-

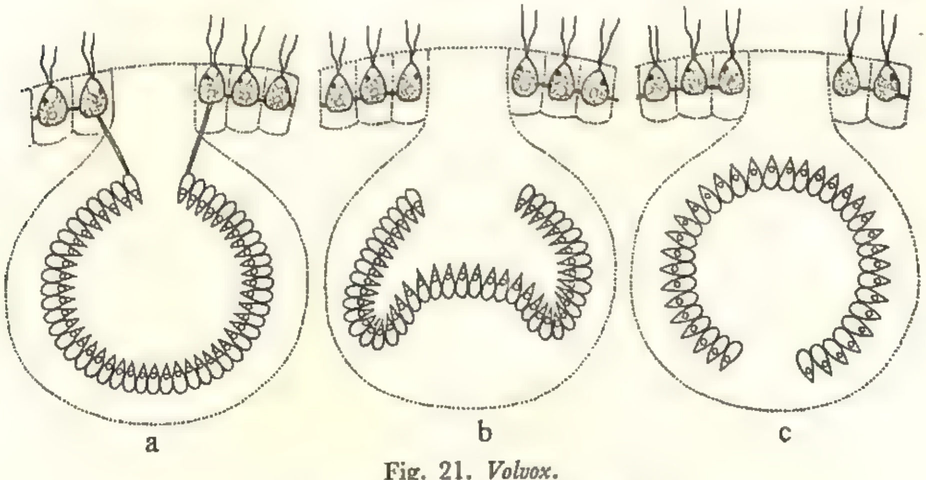


Fig. 21. *Volvox.*
a—c, Stages in the plakeal inversion.

tains a single spherical egg. The antheridium divides repeatedly and forms a bundle of 16, 32, 64, 128 or more, small, fusiform, yellowish, biflagellate bodies, the **antherozoids.**

The colony may be monoecious, or dioecious, and the same individual may or may not form gonidia.

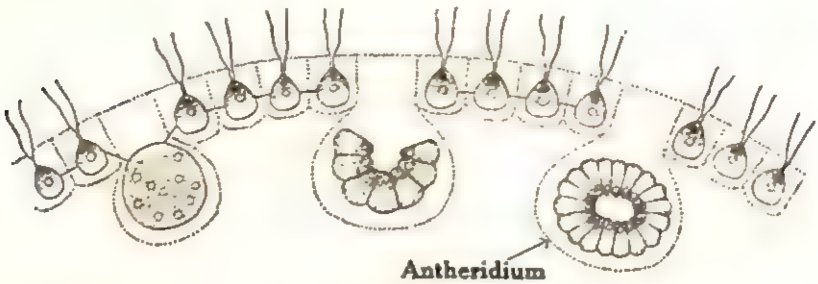


Fig. 22. *Volvox.*
A nearly mature antheridium at the right: at the left a zoospore which has lost its flagella and is starting to form an antheridium.

The mature antherozoids escape from the colony, either as free-swimming individuals, or as a free-swimming colony that dissociates into individual male gametes later on. The antherozoids, attracted by an egg, make their way through the gelatinous envelope, which surrounds the egg, but only one of them finally unites with the egg and forms the zygote (oospore).

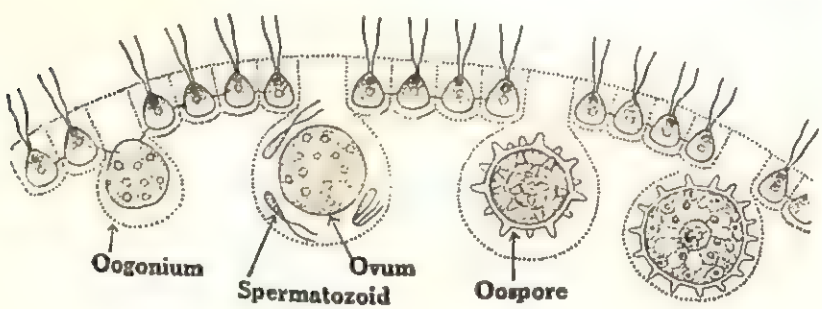


Fig. 23. *Volvox.*
At the left, a zoospore which has lost flagella is starting to form an egg; next to that is an egg just before fertilization; at the right, mature zygotes are seen.

The zygote develops a thick wall and is retained within the colony until its decay. Then it falls to the bottom of the pool and undergoes a period of rest. Finally, the wall of the zygote breaks and the protoplast comes out. It divides and soon forms a free-swimming colony of the *Volvox* plant.

ORDER 2. CHLOROCOCCALES

Unicellular or colonial ; non-motile in the vegetative condition ; reproduce by zoospores or aplanospores ; almost exclusively freshwater.

HYDRODICTYON

(Fam. HYDRODICTYACEAE)

Hydrodictyon, commonly known as the 'water-net', is a rare alga. It occurs, often in considerable quantity, in stagnant water of permanent pools or other bodies.

Of the known species, *H. reticulatum* is the most common and is comparatively widely distributed. *H. indicum*, a new species from Madras, has been described by Iyenger.

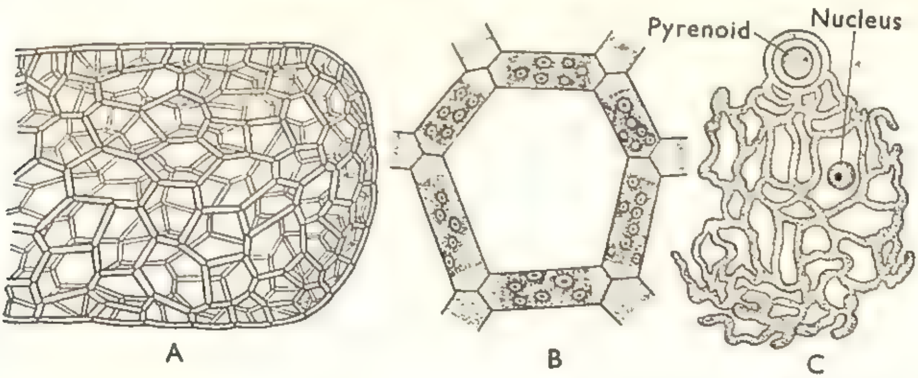


Fig. 24. *Hydrodictyon*.
A, A portion of the thallus showing the network; B, A group of cells; C, Part of the chloroplast showing the pyrenoid and a nucleus.

Vegetative body

All species of *Hydrodictyon* form colonies of a definite number of cylindrical or ovoid cells (coenobia) which are united to form a free-floating, hollow, cylindrical network, usually closed at either ends and reaching a length as much as 15-30 cm. The meshes of the reticulum are formed by the union of elongated cells. Each mature cell is multinucleate and the nuclei lie in the peripheral layer of cytoplasm internal to the cell wall and surrounding a large central vacuole. The chloroplast is peripheral, reticulate and possesses numerous pyrenoids.

Reproduction

Hydrodictyon reproduces both asexually and sexually.

Any cell of the coenobium may form zoospores, but the adjacent cells may or may not show any sign of zoospore-formation. Thousands of uninucleate, biflagellate zoospores are produced from

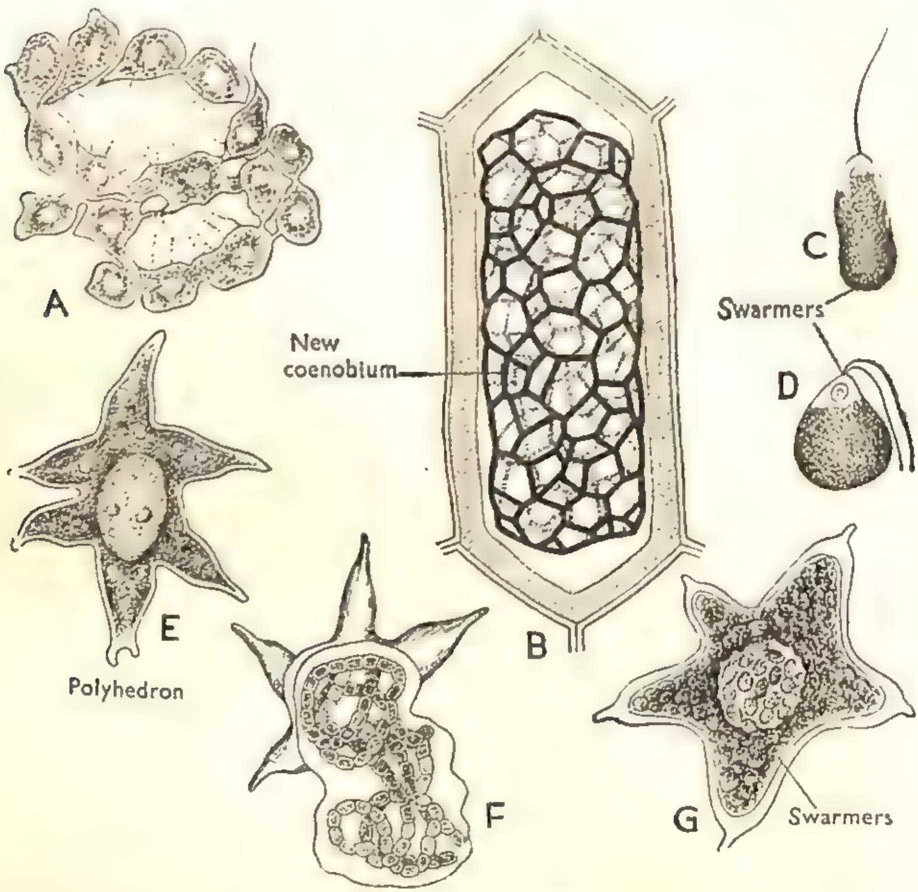


Fig. 25. *Hydrodictyon*.
A, A part of the protoplast undergoing fission to form zoospores; B, Formation of new coenobium; C—D, Swarmers; E, Polyhedron stage; F, Formation of a net within the polyhedron; G, Formation of swarmers within the polyhedron.

the protoplasm of the mature coenocytic cells by progressive cleavages. They do not escape from the mother cell, but remain confined within the wall of the parent coenocyte and exhibit a somewhat restricted movement. The necessary space for the

movement of the zoospores is provided by the extension of the longitudinal cell walls and by the diminution in size of the vacuole. They finally come to rest, arrange themselves in straight rows in three directions and touching one another withdraw their flagella, secrete membranes and form a new coenobium by the elongation of these cells. The young coenobium at first remains enclosed within the mother cell wall, which later on gelatinizes and liberates the new coenobium.

Hydrodictyon is monoecious and the **isogametes** formed from the same coenobium may conjugate in pairs. The gametes are produced in the same way as the zoospores but they are much smaller in size. Further, they are liberated from a parent cell through a hole in the cell wall. After fusion of two gametes, their flagella are withdrawn immediately and a spherical zygote with a thin cell wall results. This zygote gradually increases in size, appears red in colour due to formation of haematochrome and accumulates oil as reserve food. After a period of rest, this zygote nucleus undergoes reduction division and the protoplast is divided into four large, biflagellate zoospores. Each zoospore contains numerous discoid chloroplasts without pyrenoids. They are finally liberated by the rupture of the wall of the zygote and swim for some time. After the period of swimming, a zoospore comes to rest and develops to form a polyhedral cell resembling some species of *Tetraedron*. This may be regarded as an aplanospore. This polyhedral cell greatly increases in size forming zoospores in the usual way, and these again unite to form a new coenobium, which is liberated by the rupture of the cell wall.

PEDIASTRUM

(Fam. Hydrodictyaceae)

Pediastrum occurs as a freshwater free-floating organism, commonly in ponds, ditches and lakes. Occasionally, however, it also occurs in permanent or semipermanent ponds and ditches.

The common Indian species of *Pediastrum* are *P. simplex*, *P. clathratum*, *P. duplex*, *P. tetras*, etc.

Vegetative body

The body of *Pediastrum* is usually a single-layered coenobium

consisting of a few to several cells some multiple of 2) and are commonly arranged in distinct rings around the central cell. The cells fit closely together with their plane faces or their walls may be lobed so that small spaces of variable size are found between them.

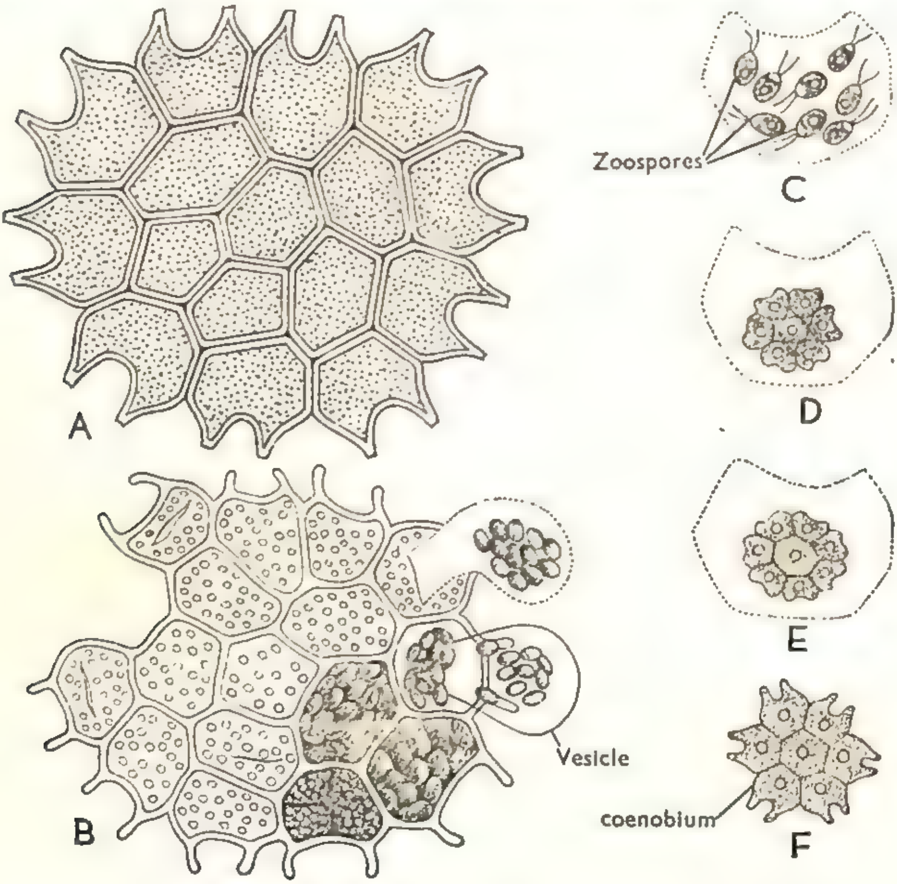


Fig. 26. *Pediastrum*.
A, A colony; B, Liberation of zoospores; C, Zoospores enclosed within a vesicle; D—F, Stages in the formation of a daughter colony.

The peripheral cells produce, on their outer faces, diverging processes, one or two from each, and they differ in shape from the internal cells. Each adult cell is multinucleate (2-8) with a single parietal plate-like chloroplast containing one to four pyrenoids. The chloroplasts sometimes show definite perforations.

Reproduction

Pėdiastrum reproduces both by asexual and sexual methods.

Asexual reproduction takes place by the formation of biflagellate zoospores. Every cell of the coenobium is capable of forming zoospores. The protoplast of a cell, following successive nuclear divisions and progressive cleavages, forms **zoospores.** These are

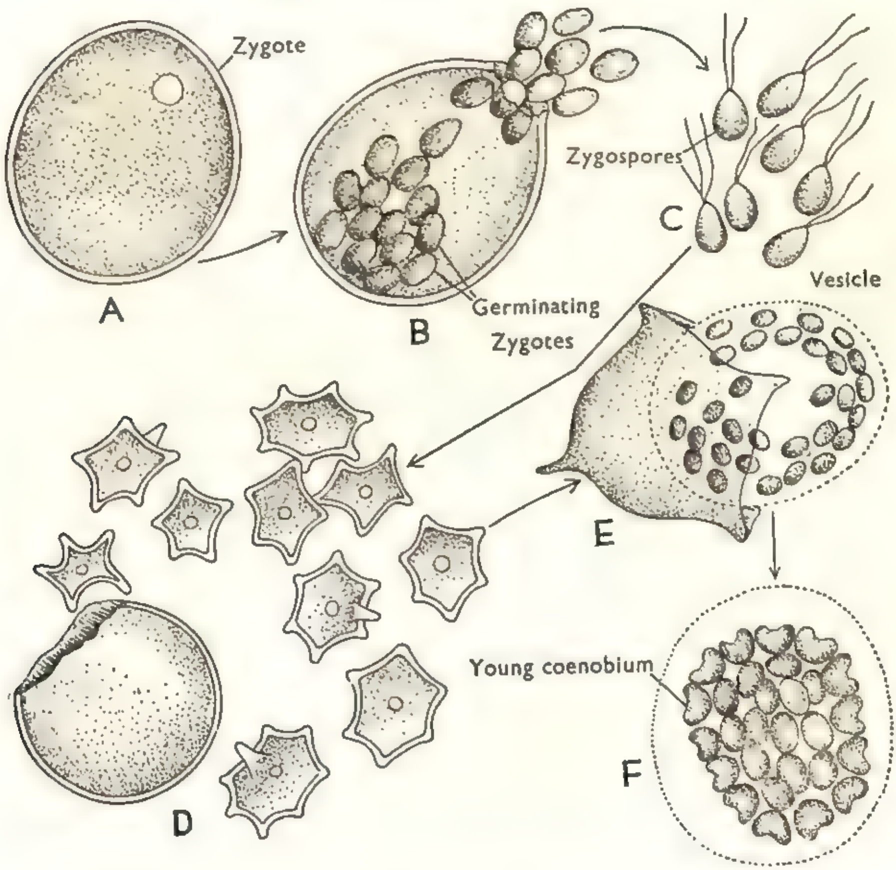


Fig. 27. *Pediastrum.*
A, A zygote; B, A germinating zygote; C, Zoospores produced on germination of a zygote; D, An empty zygote and angular cells developed from zoospores; E—F, Germination of an angular cell to form a new coenobium.

suddenly liberated due to rupture of the cell wall into a newly-formed vesicle within which they move about actively, but finally arrange themselves in one plane to form a new coenobium before liberation.

Sexual reproduction in *Pediastrum* has been reported in some species in which it takes place by the formation of biflagellate

gametes that unite to form a spherical zygote. Details of germination of the zygote are not known, but the presence of *Tetraedron stage* like that of *Hydrodictyon* has been observed in some cases. This suggests that germination of the zygote probably takes place as in *Hydrodictyon*.

Besides asexual and sexual reproduction thick-walled **aplanospores** (one or more) may develop from the entire protoplast in rare cases. These aplanospores are very resistive to adverse conditions and finally germinate.

ORDER 3. ULOTRICHALES

Filamentous, simple and unbranched or cellular expanse with small cells ; chloroplasts parietal, axial or stellate ; sometimes filaments simple and with large multinucleate cells ; mostly isogamous ; most species freshwater, some are marine.

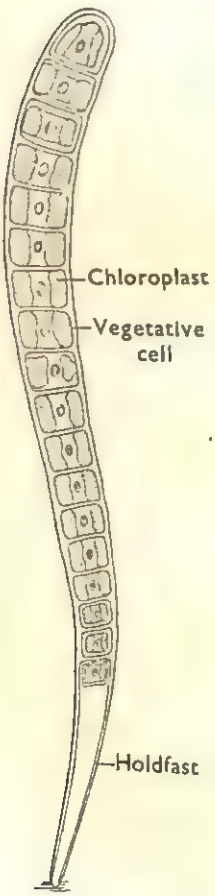


Fig. 28. *Ulothrix*. Holdfast and the vegetative cells.

ULOTHRIX

(Fam. ULOTRICHACEAE)

The majority of the species of this green alga are inhabitants of freshwater, while a few are marine.

The common Indian species of *Ulothrix* are *U. aequalis*, *U. pectinalis*, *U. zonata*, *U. variabilis*, etc.

Vegetative body

The vegetative body is a thallus which is an unbranched filament of indefinite length, consisting of a single row of short, cylindrical cells joined end on end. The filament is differentiated into base and apex, since its basal cell is colourless, elongated and gradually narrowed to form a **holdfast,** which helps in its attachment to the substratum. Each cell possesses either a thick or a thin cell wall, which often becomes stratified. The protoplast

of each cell is always uninucleate and contains a single girdle-shaped chloroplast, which encircles it partially or completely. The chloroplast contains one to several pyrenoids.

Reproduction

Ulothrix reproduces in a variety of ways mentioned below.

Vegetative reproduction takes place usually by the accidental breaking of the filament into many fragments with a few cells in each.

Asexual reproduction takes place by the formation of zoospores, which develop from the protoplasts of ordinary vegetative cells excepting the holdfast. According to species, the number of zoospores produced from each protoplast may be 1, 2, 4, 8, 16, or 32. In any case, during the formation of zoospores there is a slight contraction of the protoplast followed by nuclear division (and subsequent cleavage of the cytoplasm forming two daughter protoplasts, and this process may continue until 32 daughter protoplasts are formed. Each daughter protoplast is then usually metamorphozed into a **quadriflagellate zoospore.** When a single zoospore is formed the protoplast of the entire vegetative cell is directly metamorphozed into it. Each zoospore is pyriform in shape with a stellate chloroplast at the posterior end and a prominent eyespot and is either (*a*) large, 4-flagellate, with an anterior eyespot, called **macrozoospore,** or (*b*) small, 4- or 2-flagellate, with a median eyespot, called **microzoospore.** The zoospores are liberated through a pore on the lateral wall of the parent cell. They swim actively in water from one to several days, but ultimately cease their movement and attach themselves to some objects in water by the flagellate end. Finally, the flagella disappear, a wall is secreted around each, and by elongation of the cell and subsequent divisions a new plant is formed.

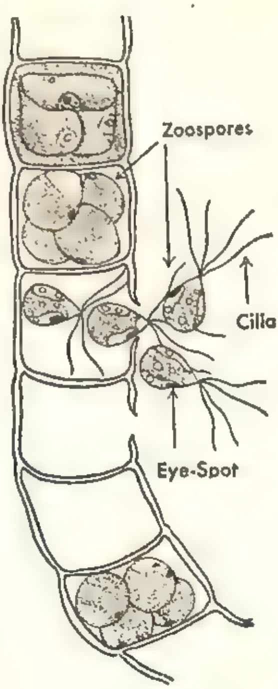


Fig. 29. *Ulothrix.* A portion of the filament showing the formation of zoospores.

When zoospores are not liberated from the parent cells, each of them secretes a cell

wall around it and forms a thin-walled **aplanospore.** The aplanospores may germinate even before liberation from the parent cell. In some cases, the protoplast of a vegetative cell may be directly metamorphozed into a single thick-walled aplanospore which ultimately germinates into a new plant.

The sexual reproduction is **isogamous,** which takes place by the union of two flagellate gametes of equal size. But the fusing gametes come from different plants. Hence, the plant is dioecious (heterothallic).

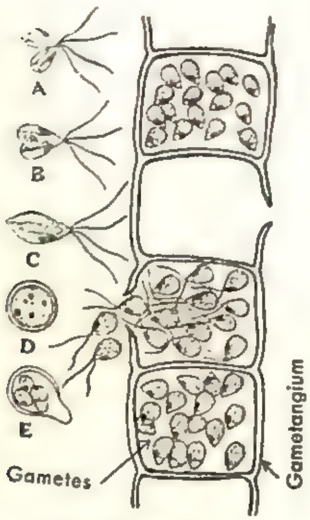


Fig. 30. *Ulothrix.* A portion of the filament showing the formation of gametes.

The formation of gametes, as well as their mode of liberation from the parent cell, takes place in the same manner as the zoospores. The number of gametes produced may be 8, 16, 32, or 64. Each gamete is **biflagellate,** pyriform, with a conspicuous eyespot and smaller in size than a zoospore. After gametic union a quadriflagellate zygote is formed, which remains motile for a time but ultimately comes to rest, secretes a thick wall around it and after accumulation of considerable amount of food-reserve passes into the resting period. At the end of the resting period, the *zygote nucleus undergoes reduction division* and forms 4 to 16 daughter nuclei, from which either zoospores or aplanospores are produced. The zoospores or aplanospores under favourable conditions develop into new plants.

ULVA

(Fam. Ulvaceae)

Ulva is the common 'sea lettuce' of the mid-tidal zone of seas of both the hemispheres. Some of the marine species are also to be found growing in brackish waters. It also grows luxuriantly in the sewage-polluted water. It is an edible alga.

The common Indian species of *Ulva* are *U. fasciata*, *U. oxycocca*, *U. lobata*, etc.

Vegetative body

The vegetative body is an expanded thalloid sheet of two-celled thickness. From the lower end of the thallus some cells give rise to rhizoidal outgrowths, which help to fix the plant to the substratum. These outgrowths finally become closely attached to one

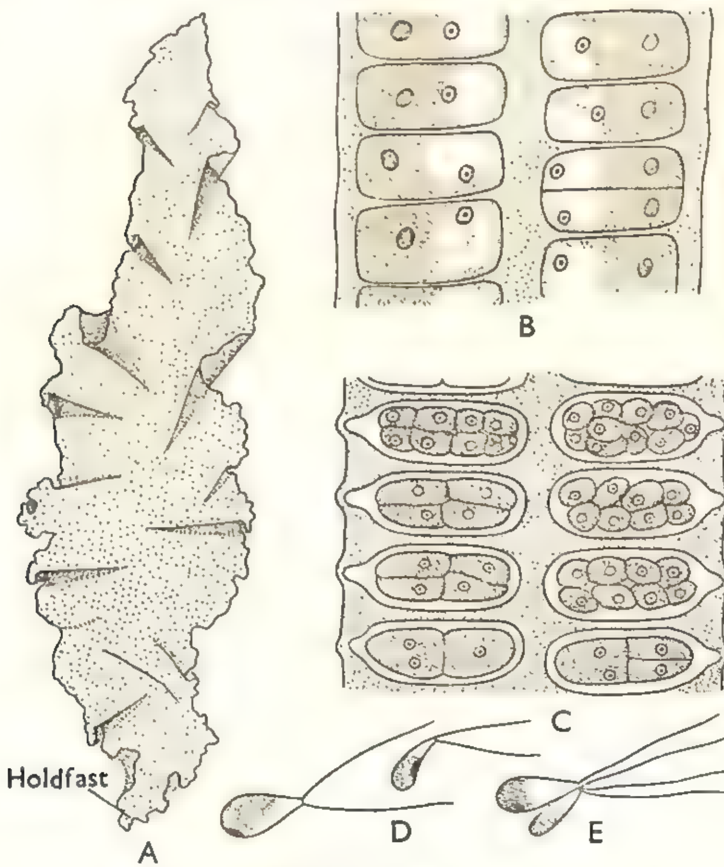


Fig. 31. *Ulva.*
A, The plant body; B, A portion of the thallus showing cell arrangement; C, Formation of gametes; D, Gametes; E, Union of gametes.

another, and give rise to a pseudoparenchymatous holdfast, which is perennial in nature and bears new **blades** every year during the spring. In cross-sectional view, the cells of the thallus are more or

less isodiametric or somewhat vertically elongated to the surface of the thallus, and their walls are somewhat fused with one another forming a matrix, which is rather thick and gelatinous in consistency. Each cell contains towards its inner face a solitary nucleus, and towards its outer face there is a single laminate to cup-shaped chloroplast with one pyrenoid only. New cells are formed by divisions of pre-existing cells in perpendicular directions to the surface of the thallus.

Reproduction

Ulva reproduces vegetatively, asexually, as well as sexually.

Vegetative reproduction in *Ulva* takes place by accidental fragmentation of the thallus growing usually in quiet estuarine waters.

Asexual reproduction takes place with the help of **quadriflagellate zoospores,** produced within the vegetative cells of the thallus. At first the cells which are near the margin of the thallus produce zoospores, and then the remoter ones. The production of zoospores goes on until, practically speaking, all the cells have behaved like zoosporangia. The zoospores come out through a pore in the cell wall, swim for a very short duration, come to rest, and then secrete a wall. A zoospore germinates to give rise to a new sexual plant.

The majority of the species of *Ulva* are heterothallic. The gametes are generally isogametes, but *U. lobata* appears to be anisogamic. The protoplast of a vegetative cell undergoes repeated cleavages until sixteen or thirty-two daughter protoplasts are formed within the parent cell. Finally, each of these protoplasts becomes metamorphozed into a single biflagellate gamete. The gametes come out through a pore developed on the cell wall. The discharge of the gametes is sometimes so very copious that the water turns green in colour. Each gamete possesses a single chloroplast and a prominent eyespot, and is pyriform in shape. Gametes unite in pairs to form a zygote. The zygote is a first quadriflagellate; it swims for a short while, comes to rest by withdrawing the flagella, and secretes a wall around itself. The zygote undergoes germination within 24-48 hours after rest, and an equational division of the zygote nucleus takes place. As a result, ultimately new diploid plants are produced. In some cases haploid thalli are developed parthenogenetically from the gametes.

It is of interest to note that in the life-history cycle of *Ulva* an isomorphic alternation of generations can be traced. Morphologically the two types of plants, the sporophyte and the gametophyte, are identical. The sporophytic thallus produces the haploid zoospores, which develop into gametophytes. The zygotes, produced by the union of gametes developed on these gametophytes, give rise to new diploid thalli.

ENTEROMORPHA

(Fam. ULVACEAE)

Enteromorpha grows in saline habitat. There are a few species under the genus, of which *E. intestinalis* is widely distributed. The other common Indian species of *Entomorpha* are *E. prolifera*, *E. compressa*, etc.

Vegetative body

At the very beginning the thallus is an uniseriate filament; very soon it becomes multiseriate and tube-like in appearance. The thallus is branched at intervals and exhibits some diversities of form. In a large number of species the thallus is attached to the substratum by means of **rhizoids,** while others, particularly those inhabiting salt marshes, remain free-floating, either throughout their life or at least a part of it; one species (*E. nana*) possesses a basal prostrate region. The branching depends upon two major external factors,—the degree of salinity in the substratum and temperature. It has further been recorded that the thallus has

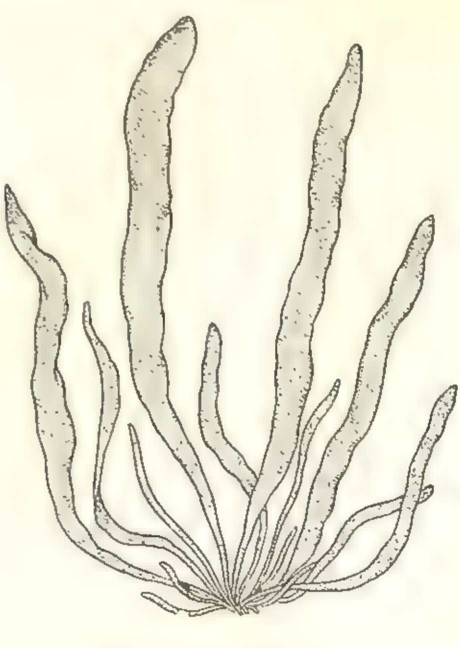


Fig. 32. *Enteromorpha*. Plant body.

got some power of regeneration. If any injury takes place near about the apex, papillate outgrowths appear from the injured cells, whereas if the basal region is subjected to an injury rhizoids are developed. The cells of the thallus are somewhat tubular, much longer than broad, and contain a number of chromatophores, with pyrenoids.

Reproduction

Enteromorpha reproduces both asexually and sexually.

The asexual reproduction takes place by means of **zoospores,** as in *Ulva*. Each zoospore on germination gives rise to a new haploid plant. In the species (*E. nana* and *E. procera*) diploid zoospores are produced, and these are termed as **neutrospores,** or neutral spores.

Enteromorpha is heterothallic and the mode of sexual reproduction is usually isogamous. An anisogamous type of reproduction is, however, found in *E. intestinalis*, where the smaller gamete with a rudimentary pyrenoid is regarded as a male one. As a result of fusion between two motile gametes a zygote is formed, which also remains motile for about an hour. After this period the flagella are withdrawn and the motility ceases, but the division of the zygote does not commence before several days.

In some species like *E. clatharta* there is no union of gametes. On the other hand, some of the cells of the gametangial region, which fail to divide and thereby give rise to gametes **(rest cells)** germinate afterwards developing into new haploid plants. These ultimately get detached from the parent plant and live as independent ones.

Enteromorpha exhibits an isomorphic alternation of generations.

ORDER 4. CLADOPHORALES

Simple or branched, filamentous with cells containing two to many nuclei and usually with elaborate large chloroplasts; mostly isogamous; freshwater and marine.

CLADOPHORA

(Fam. Cladophoraceae)

Cladophora is one of the largest genera of green algae. It occurs both in the freshwater as well as in the sea, and is widely distributed

throughout the world. In many lakes it sometimes spreads to their bottom and extends upto a depth of 24 metres. In some species the different thalli are held together by interlacing branches, often forming compact cushions attached mainly to some substratum, or loose hollow balls as big as human head.

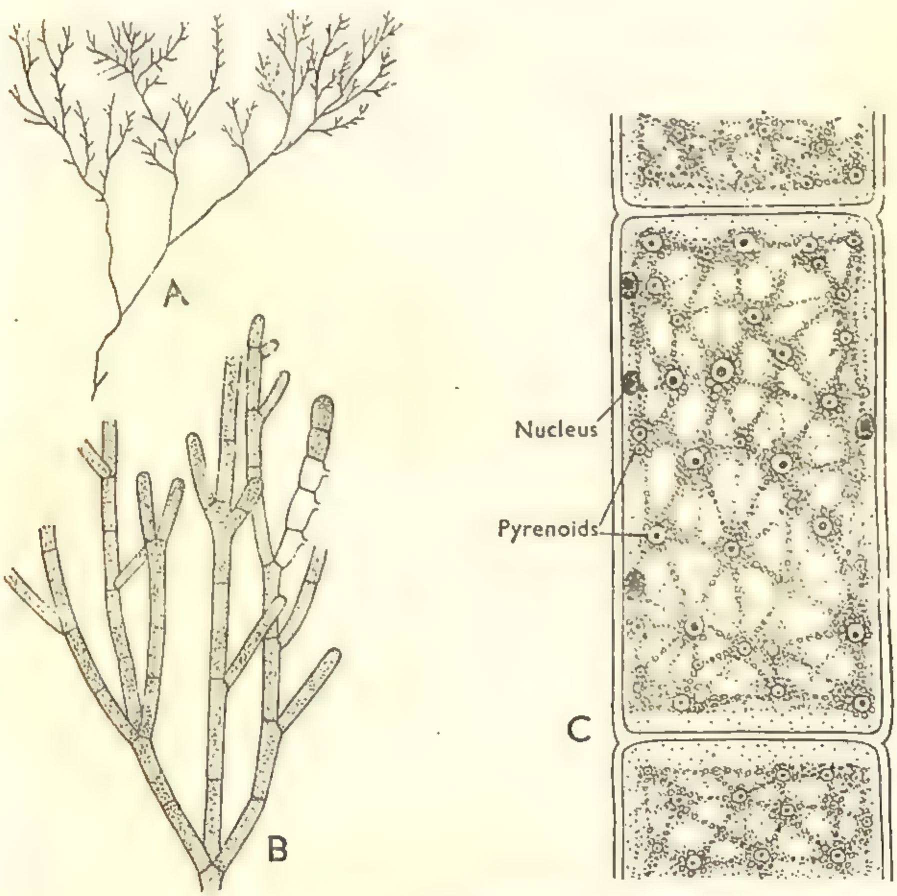


Fig. 33. *Cladophora*.
A, General habit of the plant; B, A portion of the thallus (magnified); C, A part of B magnified to show the cell structure.

The common Indian species of *Cladophora* are *C. bengalensis*, *C. glomerata*, *C. crispata*, *C. incurvata*, *C. codioia*, *C. scitula*, etc.

Vegetative body

The vegetative body is a much-branched thallus which remains attached to the substratum by long rhizoidal branches, many of

which develop adventitiously from several cells near the base of the thallus. Each branch is made up of a row of elongated cylindrical cells joined end to end. A branch always arises as a lateral outgrowth from the upper end of a cell situated towards the apical portion of the filament.

Each cell consists of a stratified cell wall made up of an inner cellulose layer, a middle pectic zone and an outer chitinous layer.

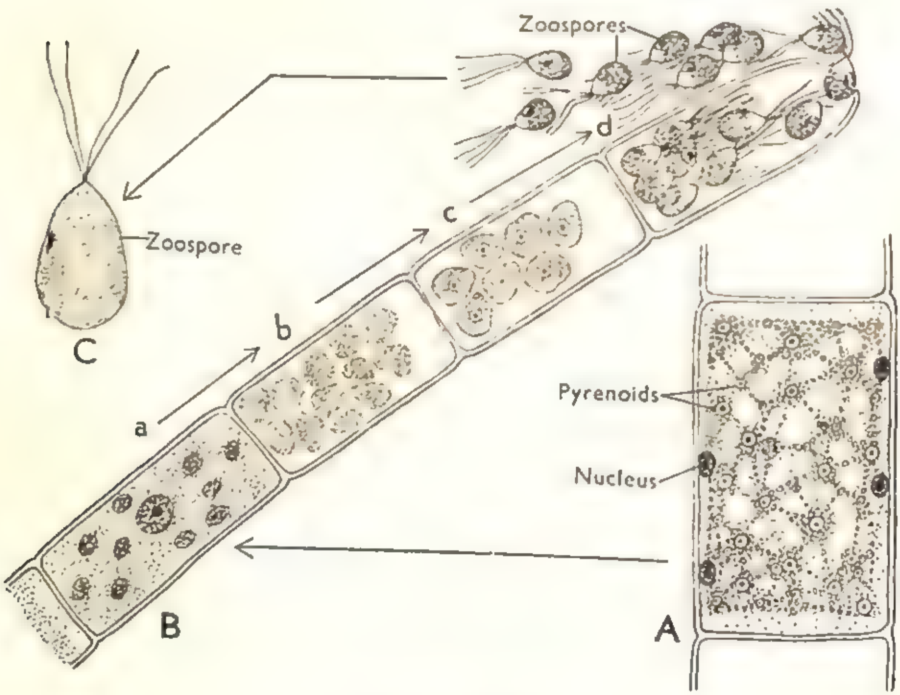


Fig. 34. *Cladophora.*
A—C, Stages in the formation of zoospores.

The protoplasm is, in most cases, multinucleate and the cytoplasm appears in the form of a primordial utricle surrounding a central vacuole. As regards the nature of the choloroplast, there is still much difference of opinion among the algologists. Possibly, the chloroplast is fundamentally a parietal reticulate structure with inward processes and numerous scattered pyrenoids. According to the most recent view, however, the mature chloroplast is regarded to be composed of numerous discoid chloroplasts with pyrenoids.

Reproduction

Cladophora reproduces by vegetative, asexual and sexual methods.

In some species during vegetative reproduction the erect portion of the thallus dies back, while the rhizoidal system persists. Many of the cells of the rhizoid become swollen and assume pear-shaped form. These thick-walled cells usually develop from unbranched rhizoidal branches. After a period of dormancy and under favourable conditions, these cells give rise to new erect filaments. This is an instance of akinete-formation without dissociation of the branches. In some cases, cells of the rhizoids get dissociated and each cell can give rise to a new thallus.

Asexual reproduction takes place by means of **biflagellate** or **quadriflagellate zoospores** formed by the cleavage of the protoplasts of vegetative cells of the younger apical filaments in basipetal succession. Before the formation of zoospores, the nuclei multiply by divisions and in some species it has been recorded that meiosis takes place at this stage. At the distal end of the mother cell a pore is formed through which zoospores escape singly. Each zoospore ultimately develops into a **germling,** which develops into two branches, one of which gives rise to the erect portion, the other to the rhizoidal system.

Sexual reproduction takes place by means of **biflagellate gametes.** The modes of formation and liberation of gametes are much the same as those of the zoospores. Certain species are definitely heterothallic and the fusing gametes belong to different thalli. Reproduction is isogamous. After fusion a zygote is formed, which directly develops into a diploid plant.

In some species, when conjugation fails, **parthenospores** are produced directly from the gametes. Each parthenospore is haploid, and, on germination, gives rise to the thallus of the same generation.

In some species of *Cladophora* there is an alternation of diploid asexual generation with a haploid sexual generation, which are morphologically alike.

ORDER 5. CHAETOPHORALES

Filamentous and sharply differentiated into prostrate and erect portions (**heterotrichous**) ; erect portion often reduced and the

prostrate portion often forming discoid expanse ; hairs of diverse types are often present ; mostly isogamous and freshwater.

CHAETOPHORA

(Fam. CHAETOPHORACEAE)

Chaetophora is abundantly found as an epiphyte on submerged water plants. It also occurs in stagnant water being attached to stone and woodwork.

The common Indian species of *Chaetophora* are *C. chlorotica*, *C. pisiformis*, *C. elegans*, *C. incrassata*, etc.

Vegetative body

The vegetative body is of definite macroscopic form. It is exceedingly tough and is made up of globular, irregularly tuberculate or elongated thallus; when globular, the thallus is differentiated into a palmelloid base and radiating branches showing different degrees of branching. Each branch is surrounded by a tough gelatinous sheath, which may or may not be fused with the sheaths of other branches. The palmelloid portion of the thallus is usually impregnated with calcium carbonate. The elongated thallus, on the other hand, has an axial strand made up of

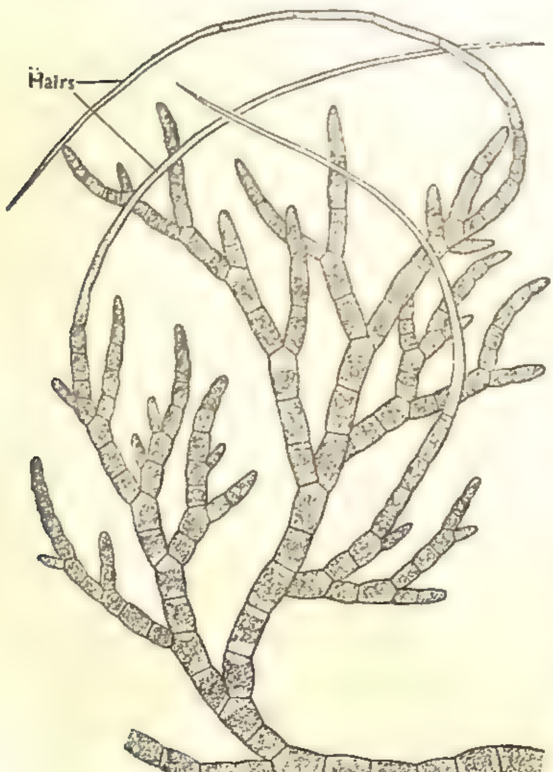


Fig. 35. *Chaetophora*.
A portion of the thallus body.

intertwined filaments which bear branches throughout its entire length. In both cases, however, the apices of the branches are prolonged into multicellular, hyaline hairs, which gradually become attenuated into a fine point.

The mature cells are somewhat cylindrical to barrel-shaped containing a protoplast having a transverse zonate band of chloroplast with many pyrenoids. In young cells, the chloroplast is peripheral in position; it covers the entire sidewalls and is provided with a single pyrenoid. The cells are uninucleate.

Reproduction

Chaetophora reproduces both asexually and sexually. Vegetative reproduction by fragmentation is very rare due to tough nature of the thallus. Two types of swarmers are recognized, *viz.*, (*a*) **quadriflagellate macrozoospores** and (*b*) **biflagellate microzoospores.** Both types of zoospores are developed from the protoplasts of mature vegetative cells by the usual cleavage process. These are liberated through an opening formed on the cell wall of the mother cell. The macrozoospores develop directly into new thalli. The microzoospores, on the other hand, seem to be gametic in nature, as they usually fuse in pairs forming zygotes. Sometimes, they form **resting spores** without fusion, or in rare cases grow out into new plants. Occasionally, akinetes are formed either from any part of the vegetative filament or only from the cells of the ultimate branches.

DRAPARNALDIOPSIS

(Fam. CHAETOPHORACEAE)

Of the two species of *Draparnaldiopsis*, *D. indica* was first reported to occur at Banaras, India, in a shallow water of a pond forming pale green, thin, gelatinous covering on leaves of grasses and sedges.

Vegetative body

The thallus has a main axis, which is differentiated into cylindrical, elongated and somewhat barrel-shaped internodal cells, which alternate with one another in a very regular fashion. The internodal cells are about two to three times longer than the nodal

cells. The axis is attenuated towards the apex and the base. The lowest of the basal cells forms a rhizoid, while a few other cells situated above develop rhizoidal branches forming a dense cortex around the base of the main axis.

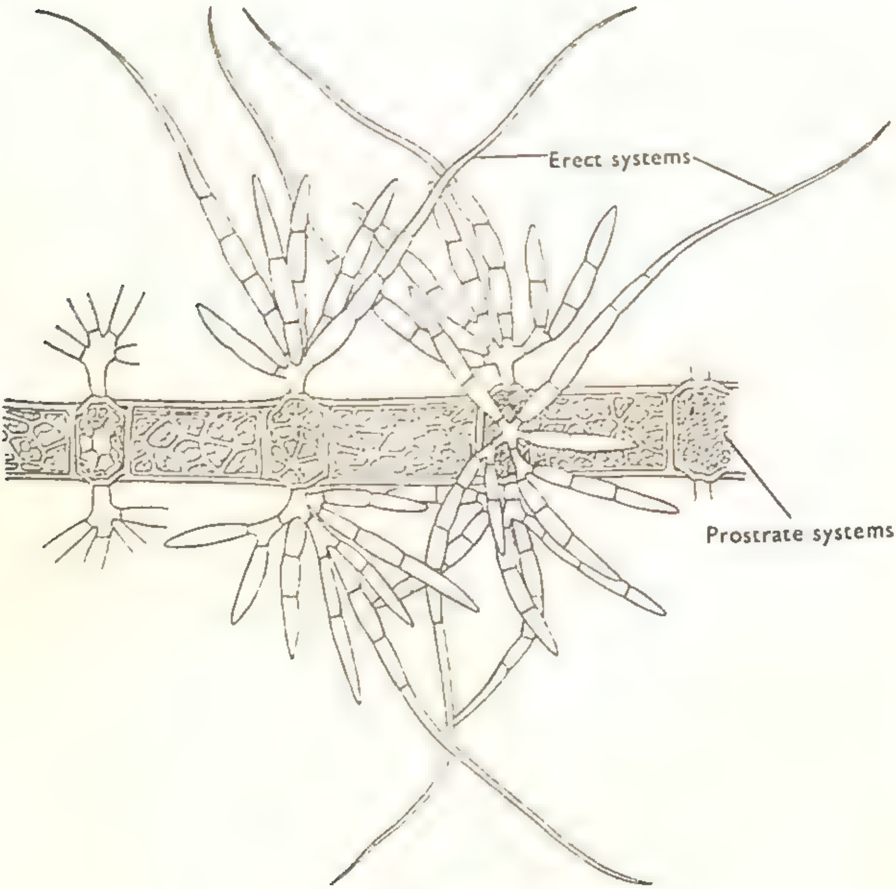


Fig. 36. *Draparnaldiopsis.*
A portion of the thallus body.

The main axis usually bears a number of lateral branches of **unlimited growth.** They arise from some of the nodal cells. Short branches of **limited growth** also arise from the nodal cells as oppposite pairs in whorls of four. They may develop also on the branches of unlimited growth. Some of the nodal cells may bear both branches of limited and unlimited growth.

The branches of limited growth form more or less orbicular clusters due to their spreading character. Each branch is subulate

and is terminated in a long, hyaline hair at the distal end. In this species, there is a great tendency for the transformation of branches of limited growth into rhizoid-like structures, particularly at the points where branches of unlimited growth arise. The entire thallus is enveloped by mucilage.

Chloroplasts are present in each cell excepting in the cells of hairs and rhizoids. They are parietal, reticulate and occupy the whole length of the cell. One or two pyrenoids may be present in the chloroplasts of branches of limited growth.

Rhizoids are much branched and usually are not differentiated into nodal and internodal cells. Their cells are elongated and their chloroplasts gradually disorganize and disappear.

Reproduction

Zoospore and gamete-formation have not yet been observed in this species.

TRENTEPOHLIA

(Fam. TRENTEPOHLIACEAE)

The species of *Trentepohlia* are widely distributed and are abundantly found in damp tropical and subtropical climates forming felty layers on bark of trees, rocks, leaves or various woodworks. Sometimes they are also found in temperate climates wherever abundant moisture is present for their development. The plant masses are readily recognizable by their orange-yellow or brownish-red coloured cushions, but sometimes they may form fine crusts.

The common Indian species of *Trentepohlia* are *T. abietina*, *T. calamicola*, *T. gracilis*, *T. odorata*, *T. torulosa*, *T. polycarpa*, *T. tenuis*, etc.

Vegetative body

In great majority of the species the thallus is differentiated into prostrate and erect filaments. In some cases, the erect filaments are often very little developed or may be entirely absent. In the latter case, the prostrate portion forms an almost pseudo-parenchymatous structure. The erect filaments are well branched. The branches are either alternate, opposite or unilateral and arise usually from the distal end or from the middle of the parent cells.

The cells are cylindrical or barrel-shaped with thick, stratified cellulose walls. There is usually a cap of pectose at the apex of each branch. The protoplast of each cell is uninucleate when young, but usually becomes multinucleate when old. There are always a

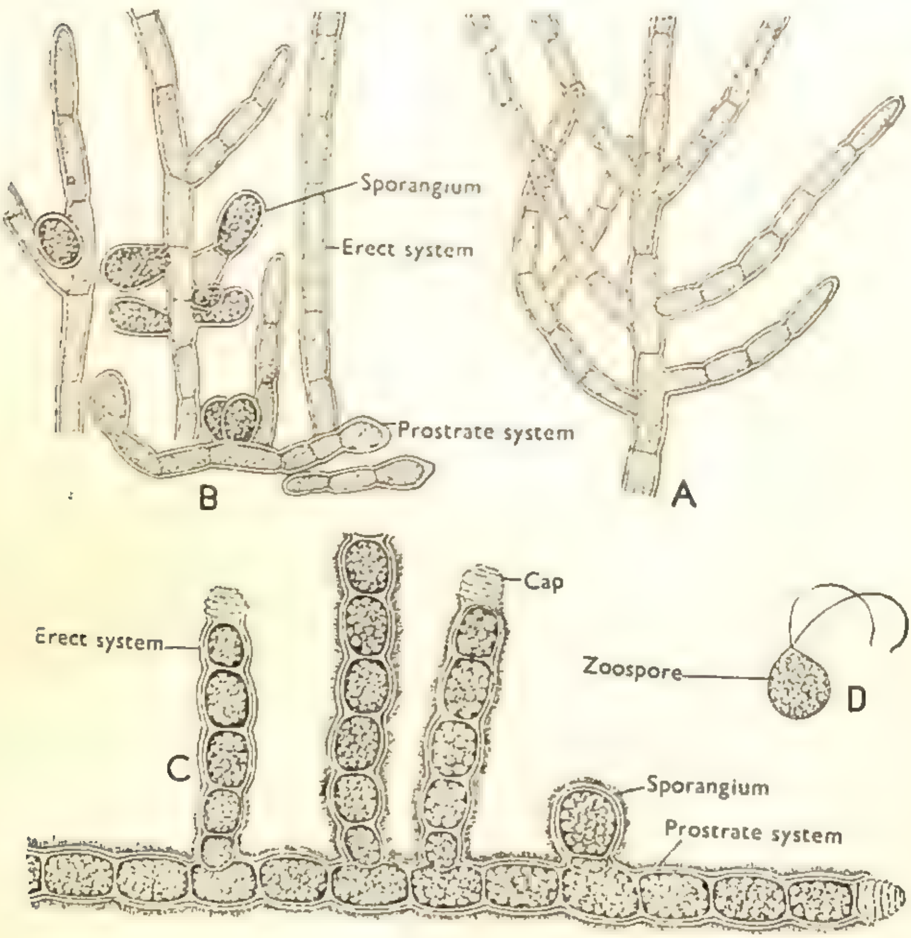


Fig. 37. *Trentepohlia.*
A, A portion of the erect system of the thallus; B, Part of the thallus with two systems of filaments and sporangia; C, Part of B magnified; D, A zoospore.

number of discoid or band-shaped parietal chloroplasts, the former type being often arranged in bands. They are often obscured by the presence of orange-red haematochrome dissolved in fat globules, which are found around the chloroplasts making the green colour of the latter.

Reproduction

Reproduction in *Trentepohlia* takes place by vegetative, asexual and sexual methods.

During vegetative reproduction detached fragments of the thallus, or rounded or ellipsoidal separated cells of the prostrate system are undoubtedly disseminated by wind, and these under favourable conditions give rise to new thalli.

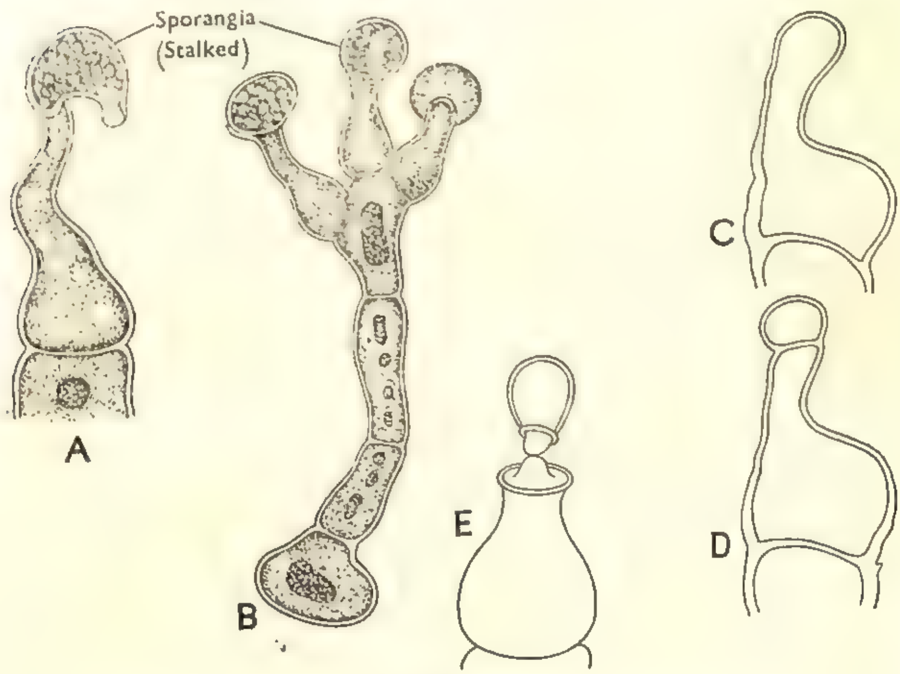


Fig. 38. *Trentepohlia*.
A—B, Portions of filament with stalked sporangia; C—E, Development and detachment of the stalked sporangium.

During the wet season the plant reproduces asexually by means of zoospores formed within special ellipsoidal or oval sporangia, mainly of two types: (*i*) **sessile,** and (*ii*) **stalked.** The sessile sporangia are formed by enlargement of cells, which may be terminal, lateral, intercalary or axillary in position. They liberate zoospores without themselves being detached from the filaments. The stalked sporangia, on the other hand, develop as terminal or lateral appendages from an enlarged supporting cell. A tubular outgrowth from the supporting cell becomes separated

by the formation of a wall and later a sporangium is cut off at its apex, and it is somewhat bent in a knee-shaped manner. The sporangia finally get detached from the stalks and produce biflagellate zoospores, while those produced by the sessile sporangia may be quadriflagellate. The zoospores ultimately give rise to new thalli again.

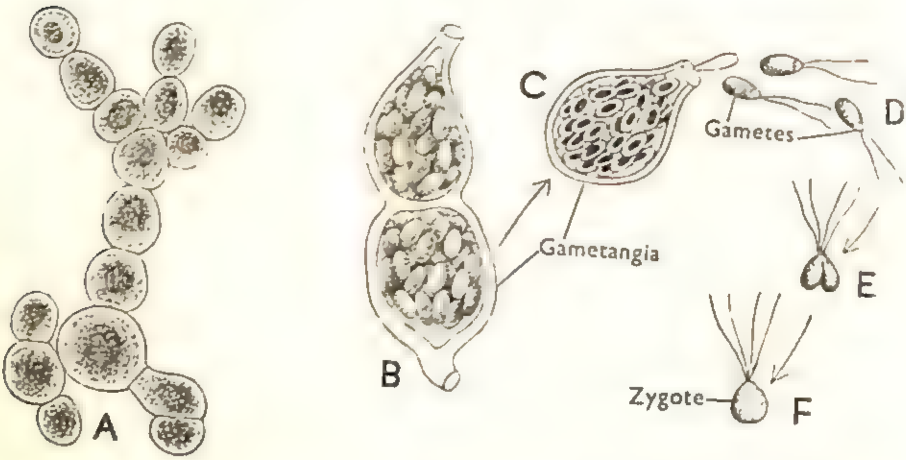


Fig. 39. *Trentepohlia.*
A, Fragment of the prostrate system of the thallus; B—F, Stages in the formation of the gametes and the development of the zygote.

Under certain conditions, the sporangia form thick-walled **aplanospores** instead of zoospores. Akinetes are also formed from several successive cells of the prostrate system which germinate directly and produce new thalli.

It has been stated by several investigators that sexual reproduction takes place in some species by the fusion of isogametes, which are identical in structure with the biflagellate zoospores. The gametangia from which they are produced are also similar to the sessile sporangia. It may be, therefore, justified in assuming that the sessile sporangia are gametangial in nature. The failure of biflagellate zoospores, produced by the same individual, to fuse in pairs may possibly be due to the heterothallic nature of some species of *Trentepohlia*. In some cases both types of reproductive structures occur on the same individual, while in others they are found on two distinct plants, which fact possibly suggests an alternation of generations.

COLEOCHAETE

(Fam. COLEOCHAETACEAE)

Coleochaete occurs abundantly in freshwater as an epiphyte on submerged plants or submerged portions of higher plants and on some green algae, *e.g.*, *Vaucheria*, *Oedogonium*, etc. It also occurs as an endophyte within the cell walls of *Chara* and *Nitella*.

The common Indian species of *Coleochaete* are *C. orbicularis*, *C. scutata* and *C. soluta*.

Vegetative body

The thalli exhibit diverse forms. In some cases, they are typically heterotrichous with numerous projecting filaments combined to form a more or less hemispherical cushion, which is surrounded by mucilage. In most cases, only the prostrate system is present and made up of either loosely-arranged branching threads, or the threads are radially arranged being attached to the substratum by means of outgrowths from the cell walls. In some cases, these radially-arranged threads are fused to form a compact, more or less discoid, one- to many-layered structures. Branching of the filaments is lateral or it is effected by dichotomy of the apical cell.

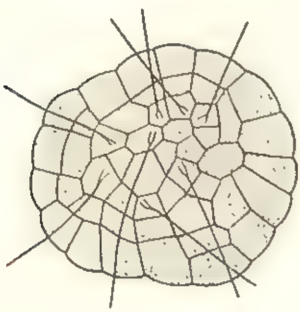


Fig. 40. *Coleochaete*. Discoid form.

The cells of the filament are uninucleate with the large, irregular, parietal chloroplast having one or two pyrenoids; usually most of the cells bear characteristic unbranched cytoplasmic bristles, each being ensheathed at its base by a cylinder of gelatinous material.

Reproduction

Coleochaete reproduces both asexually and sexually.

Asexual reproduction takes place by means of large, ovoid, **biflagellate zoospores** which are formed singly within an ordinary cell. Each zoospore is often provided with a chloroplast. The zoospore escapes through a circular opening, formed at the apex of a short papilla developed on the cell wall. It swims for an hour

or so, comes to rest, secretes a wall around it, and begins to germinate. During germination it at first divides into two cells and later forms its characteristic thallus. In some cases thick-walled **aplanospores** may develop singly within a vegetative cell.

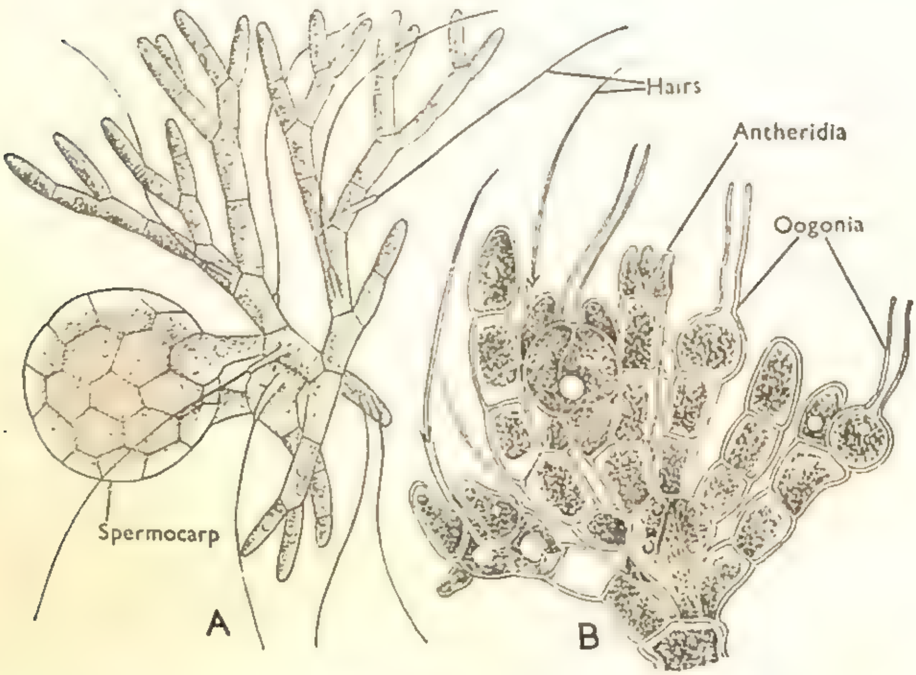


Fig. 41. *Coleochaete.*
A, A portion of the thallus bearing a spermocarp ; B, Part of the thallus showing antheridia and oogonia.

Sexual reproduction takes place by **oogamy.** *Coleochaete* may be both homothallic or heterothallic.

After fertilization, the basal portion of the oogonium is cut off from the neck by the formation of a transverse septum. Meanwhile, numerous filaments develop from the underlying cells and overgrow the oogonium. These are finally fused to form a more or less pseudoparenchymatous structure and appear reddish brown in colour. In discoid forms, these are formed only at one side away from the substratum, and a thick-walled oospore is eventually formed, whose wall is partly made up of the oogonial wall and partly of the inner walls of the investing threads. The cells of the investment finally die down and the oospore perennates for some time in this condition. During germination the oospore produces several biflagellate zoospores that

are liberated by the breaking down of its wall. These zoospores are quite different in shape from those formed during asexual reproduction. After a period of swarming they come to rest and develop

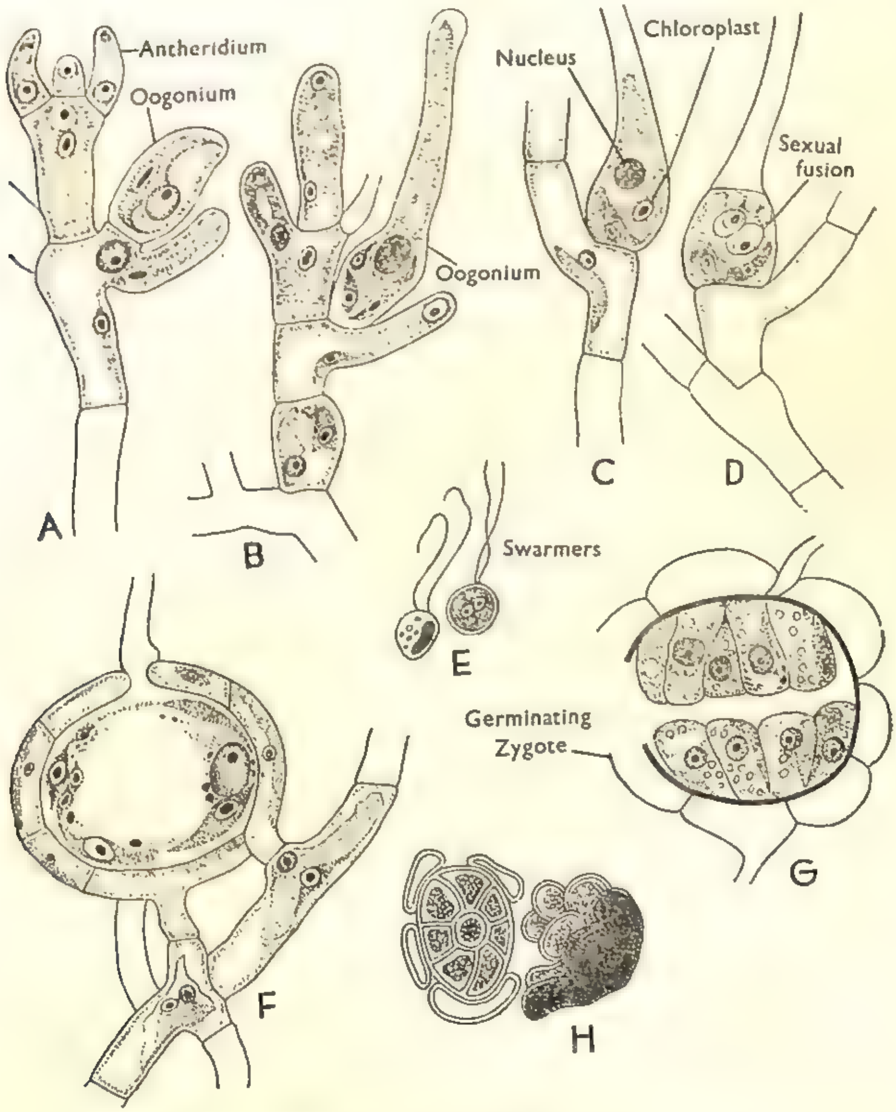


Fig. 42. *Coleochaete.*
A—G, Successive stages in the development and germination of zygote; H, Development of swarmers within two mature zygotes.

directly into new thalli. It has been demonstrated that reduction division of the zygote nucleus takes place during germination.

The oogonia are borne terminally on short lateral branches of the projecting threads. They eventually occupy a lateral position due to the development of a branch arising from a basal cell. The oogonium is flask-shaped with a basal swollen portion and an upper elongated long neck (**trichogyne**) and contains protoplasm with chloroplasts. When it attains maturity, the apical portion of the neck disintegrates, thereby exuding some amount of cytoplasm and the remaining portion of the protoplasm within the oogonium forms the ovum or egg. In discoid forms the oogonia appear as hemispherical structures with short papillae.

The antheridia are also borne terminally in clusters on the branches of the projecting systems. In homothallic species, the same branch often bears the oogonium. They arise as small, colourless outgrowths which are separated from the mother cells by the formation of septa. In discoid forms, they usually develop from the marginal cells. Each antheridium produces a single, colourless, spherical or oval spermatozoid with two apical flagella. The spermatozoids are set free by the dissolution of the wall of the antheridium at the apex.

After fertilization, the branches from the cells below the oogonium and the adjacent cells begin to grow upward and form a sheath around the oogonium. The entire structure becomes reddish brown in colour and is termed a **spermocarp.**

PROTOCOCCUS (=*PLEUROCOCCUS*)

(Fam. Protococcaceae)

Protococcus is the commonest green alga in the world, being very prevalent in the temperate regions of both hemispheres excluding those parts which are very dry. It forms a thin green coating on various substrata, such as exposed rocky surfaces, fence posts, trunks and branches of trees, etc., being generally restricted to the most shaded and moist sides. The cells of *Protococcus* are remarkably resistant to drought and can readily absorb moisture from the atmosphere, when the conditions are favourable.

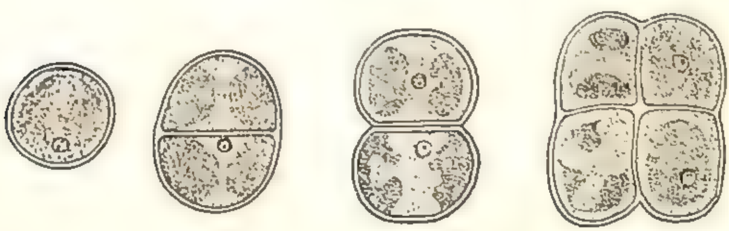
The common Indian species of *Protococcus* are *P. cohaerens*, *P. viridis*, *P. greville*, etc.

Vegetative body

The vegetative body may be unicellular, or in groups of 2, 3, 4, or rarely more cells. Each cell is spherical to ellipsoidal in form with a thick wall, devoid of any gelatinous sheath. The multicellular condition arises only due to successive divisions of the solitary cell. When growing under conditions of excessive moisture, cell divisions may continue to form colonies of 50 or more cells, and there may be a development of a profusely and irregularly branched condition (**Pseudo-pleurococcus stage**). The protoplast of each cell contains a definite nuclear membrane, and a large parietal, laminate and marginally lobed chloroplast, usually without pyrenoids.

Reproduction

Protococcus reproduces only vegetatively by means of cell division. The two or more daughter cells, thus formed, may remain attached



A B C D

Fig. 43. *Protococcus*.
A, A vegetative cell; B—D Vegetative reproduction and formation of daughter cells.

with one another for some time, or they may ultimately separate and assume a spherical shape.

ORDER 6. OEDOGONIALES

Simple or branched, filamentous ; zoospores multiflagellate ; oogamous ; cell divisions characterized by intercalation of strips of

membrane between two parts of the mother cell ; entirely freshwater.

OEDOGONIUM

(Fam. OEDOGONIACEAE)

Oedogonium is a freshwater, submerged, filamentous, green alga. It occurs in permanent or semipermanent pools or ponds. All species, at the beginning, are sessile, *i.e.*, attached to some substratum. Some remain in this condition throughout their entire length of life, while in others, filaments get detached from the substratum and float on the surface of water forming densely interwoven masses. Some are epiphytic and grow on stems and leaves of submerged aquatic vascular plants or on larger green algae.

The common Indian species of *Oedogonium* are *O. acmandrium*, *O. areolatum*, *O. armigerum*, *O. aster*, *O. elegans*, *O. calvum*, *O. glabrum*, *O. inerme*, etc.

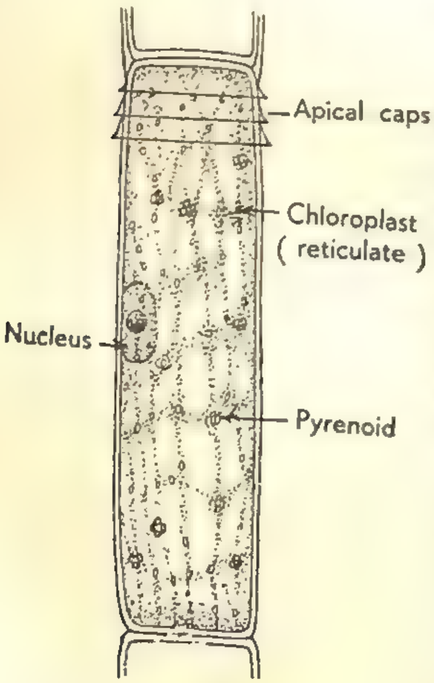


Fig. 44. *Oedogonium*. A vegetative cell.

Vegetative body

The thallus is an unbranched filament consisting of a single row of cylindrical cells joined end on end. The filament shows distinction into base and apex. The basal cell becomes modified and forms a **holdfast** by means of which the thallus fixes itself to the substratum. The apical cell is usually convex, but may be pointed.

The cell wall, though appears to be homogeneous, consists of three concentric portions: (1) an innermost cellulose layer lying in contact with the protoplast, (2) a median pectose layer, and (3) an outermost layer chiefly made up of chitin. In the basal cell this outermost chitinous layer is absent. The transverse wall of each cell towards

the distal end is provided with transverse striations which constitute the **apical cap**. Thus, the intercalary cells also show distinction into base and apex.

The protoplast, in an adult cell, lies next to the cell wall containing a single nucleus. The nucleus is large, biscuit-shaped, with one or more prominent nucleoli and a distinct nuclear reticulum. It lies midway between the two poles of a cell and is located in the peripheral layer of cytoplasm. The chloroplast is very characteristic. It is in the form of a hollow cylindrical net extending from pole to pole and is lodged on the peripheral layer of cytoplasm, external to the nucleus. There are numerous pyrenoids at the crossings of the reticulum, each being surrounded by a plate of starch. The starch grains, as they are formed, may move away from the pyrenoids and accumulate in the connecting strands of the chloroplast, thereby finally obscuring the nature of it. This is known as **stroma starch.**

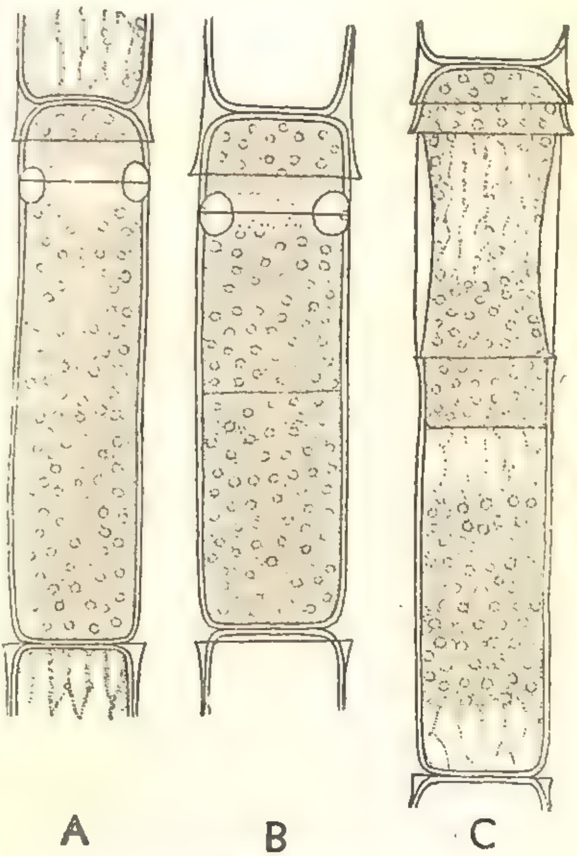


Fig. 45. *Oedogonium.*
A—C, Stages in the division of cell and formation of cap cells.

The filament elongates by division of any cell but the basal one. During cell division, a transverse ring of thickening appears at the upper end of the cell just beneath the septum. The cell wall breaks across transversely at this point, and the ring gradually extends to form a membrane across the rent. The mitotic nuclear division is followed by cytokinesis (transverse) and elongation of daughter cells to about the same

length as the mother cell. The lower one elongates until it upper end is at about the level of the ring and its lateral wall is the lateral wall of the mother cell. The upper one elongates meanwhile, and its lateral wall is formed by a stretching of the ring except for the persistent projecting portion of the ruptured mother cell wall, the apical cap. These cap cells usually divide repeatedly showing as many caps as there are divisions.

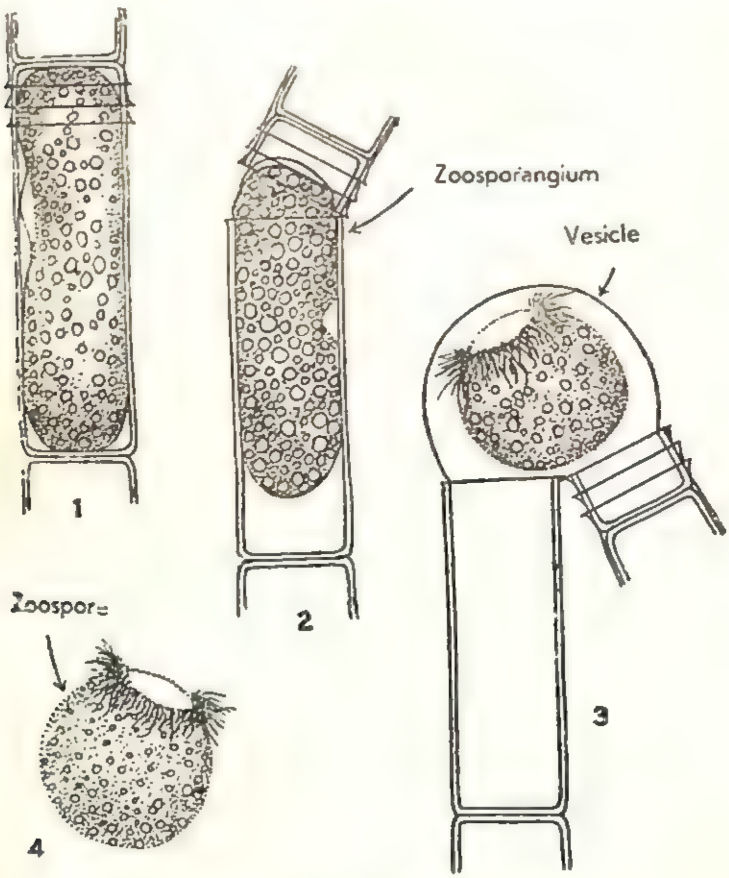


Fig. 46. *Oedogonium.*
1—3, Formation and liberation of the zoospore; 4, A mature zoospore.

Reproduction

Oedogonium reproduces by vegetative, asexual and sexual methods.

When reproduction takes place vegetatively, it is chiefly by the

accidental breaking of the filaments, and in submerged aquatic species it is by the process of fragmentation.

Most species of *Oedogonium* reproduce asexually by the production of **multiflagellate zoospores** formed within zoosporangia. Any intercalary vegetative cell, rich in accumulated oil-reserve, may become a zoosporangium and form a zoospore. During its formation, the nucleus slightly recedes inwards, and a hyaline region appears in the cytoplasm between the cell wall and the nucleus. Around the margin of this hyaline region numerous granules (**blepharoplasts**) appear, each of which probably gives rise to a flagellum. After the formation of the flagella, the cell wall breaks transversely at the region of the apical cap and the metamorphozed multiflagellate protoplast escapse as a zoospore, being enclosed by a hyaline vesicle which gradually increases in size and finally disappears liberating the zoospore in the surrounding water. The zoospore, with its crown of flagella around the base of the hyaline end, swims for some time, comes to rest on some substratum with the anterior end downwards. The flagella are finally withdrawn and the protoplast slightly elongates, develops a holdfast and finally secretes a wall around it. This one-celled plant then elongates and by repeated cell divisions gives rise to a new filament.

Sometimes *Oedogonium* may form **akinetes** in chains of 10-40, within the vegetative cells. The akinetes contain sufficient amount of reserve starch and red-coloured oil. Under favourable conditions an akinete germinates into a new plant.

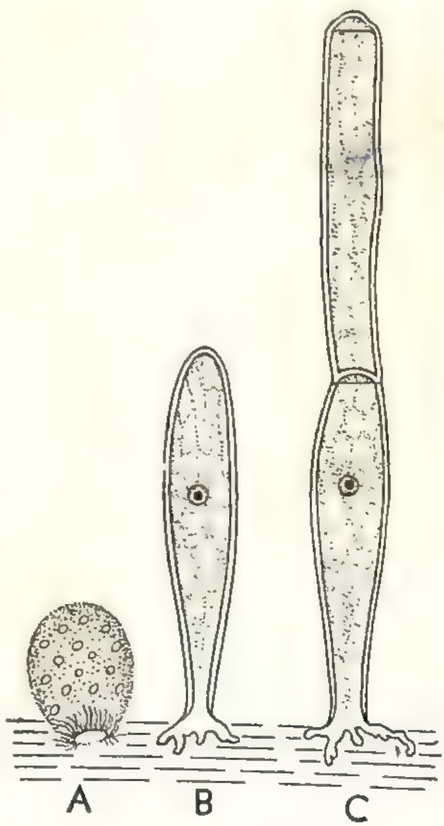


Fig. 47. *Oedogonium.* Germination of a zoospore and formation of a young plant.

(Sexual reproduction in *Oedogonium* is of an oogamous type) in which a gametic union takes place by the fusion of a small motile spermatozoid with a large, non-motile egg. (The sexual organs, antheridia and oogonia, may be produced on the filaments of normal-size (**macrandrous species**), or the oogonia are borne on normal filament, the antheridia being produced on special **dwarf male filaments** or **nannandrium** (**nannandrous species**) consisting of a few cells.)

Macrandrous species may be homothallic or heterothallic. Any vegetative cell excepting the basal one may act as an antheridium mother-cell. The position of the antheridium may be terminal or intercalary. The antheridium mother-cell divides into two daughter cells of unequal sizes, the short terminal cell being transformed into an antheridium. The lower much longer sister cell may, in turn, act as an antheridium mother-cell, and divides repeatedly in a similar manner forming a row of 8-40 antheridia. The protoplast of each antheridium is metamorphozed into a single spermatozoid, or it divides into two daughter protoplasts and forms two spermatozoids. The spermatozoids look like zoospores, but are much smaller in size and with fewer flagella. The mode of liberation of the spermatozoids is similar to that of zoospores, and there is the usual formation of a vesicle at the time of liberation.

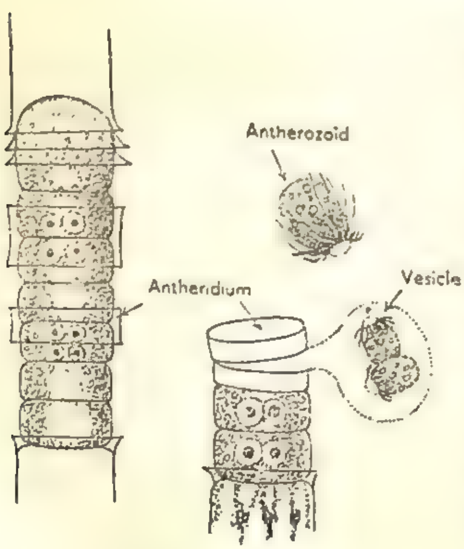


Fig. 48. *Oedogonium*. Formation of antheridia and liberation of spermatozoids.

Similarly, the terminal or any intercalary vegetative cell may act as an oogonium mother-cell. The oogonium mother-cell, as before, divides into two daughter cells of unequal sizes, the shorter cell at the distal end forms the oogonium and is always provided with one or more caps at the upper end. The lower larger sister cell is called the **suffultory cell.** This cell either remains as such or acts as another oogonium mother-

cell, which divides and re-divides forming two or more intercalary oogonia in a chain. The oogonium swells up and becomes more or

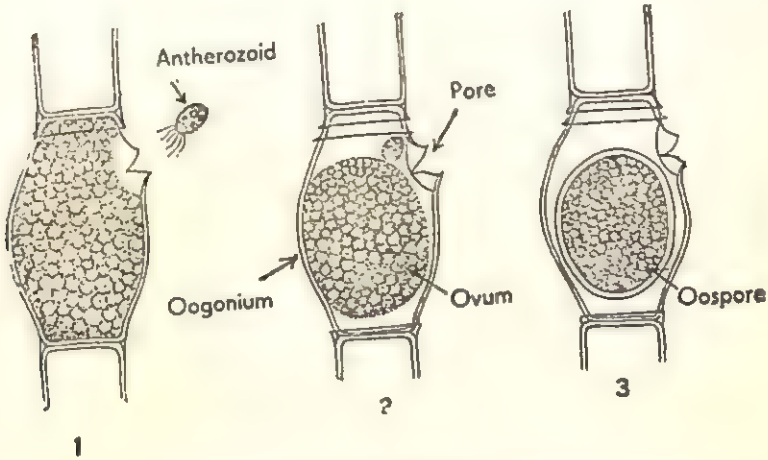


Fig. 49. *Oedogonium.*
1, An oogonium ready for fertilization; 2, The same just at the time of fertilization; 3, An oogonium with a zygote (oospore).

less spherical with a diameter greater than that of any vegetative cell. The protoplast of the oogonium is gradually metamorphozed into a uninucleate oosphere or ovum. As the oogonium approaches maturity, a small pore or transverse crack is formed on its wall towards the upper end. Just before fertilization the nucleus of the ovum migrates from the centre towards the pore, where the ovum slightly contracts from the oogonial wall and forms a hyaline receptive spot just outside the nucleus.

Nannandrous species are heterothallic. The structure and mode of development of the oogonia are similar to those in macrandrous species, and these are borne on filaments of normal size. The dwarf male filaments bearing antheridia are produced as a result of germination of the special type of zoospores, called **androspores,** formed within **androsporangia.** The mode of formation of androsporangia is similar to that of the antheridia. The protoplast of an

Fig. 50. *Oedogonium.*
Androsporangia.

androsporangium is metamorphozed into only one androspore. The androspores, similar in appearance with the spermatozoids of macrandrous species, are liberated in the same way, each being surrounded by a vesicle when first liberated. When the vesicle disappears the androspore swims freely in water and comes in the neighbourhood of an oogonium or an oogonium mother-cell. In the former case, the androspore attaches itself, with its hyaline end downwards, to the oogonial wall or to the wall of the suffultory cell and forms the dwarf male filament there. In the latter case, when it affixes itself to the wall of the oogonium mother-cell, it has been found to form the dwarf male filament always on the suffultory cell after the division and formation of oogonium. When an androspore affixes itself to the wall, it develops a holdfast, surrounds itself with a delicate wall and forms a one-celled plant (**germling**). This cell acts as an antheridium mother-cell and cuts off one or more antheridia at its apex. The protoplast of each antheridium divides into two parts and forms two spermatozoids.

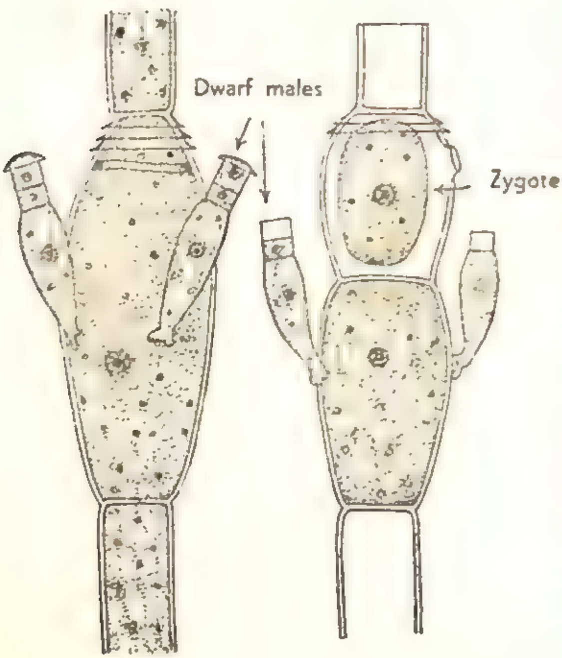


Fig. 51. *Oedogonium.* Sexual reproduction in a nannandrous species.

Nannandrous species of *Oedogonium* may bear both oogonia and androsporangia on the same filament (**gynandrosporous**), or they are borne on different filaments of normal sizes (**idioandrosporous**).

In both macrandrous and nannandrous species, fertilization of the ovum takes place by the entry of a spermatozoid through the pore at the hyaline receptive spot. The zygote (oospore) slightly retracts from the oogonial wall and soon forms a wall of two

or three concentric layers around it. The middle layer may often show pits or reticulations. At maturity, the oospore becomes reddish brown in colour due to the accumulation of oil. Finally, the oogonial wall disintegrates, the oospore falls to the bottom of the pond, where it undergoes a period of rest for a year or more. Prior to germination the diploid nucleus of the protoplast undergoes reduction division forming four haploid nuclei.

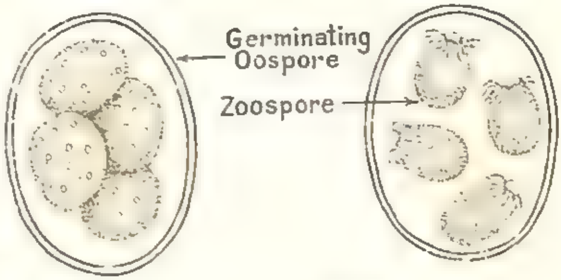


Fig. 52. *Oedogonium*. Germinating oospore.

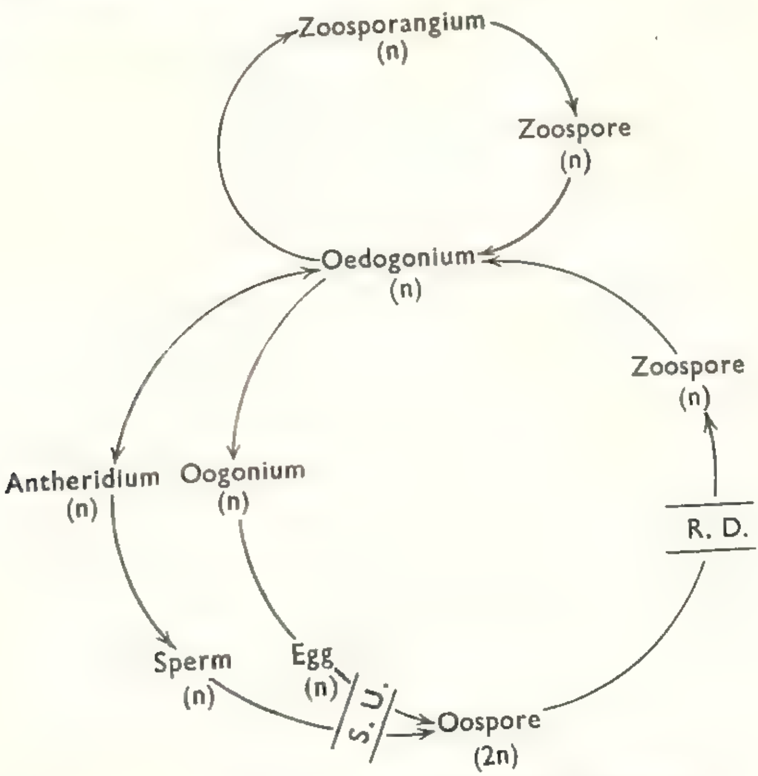


Fig. 53. Life cycle of a *macrandrous* species of *Oedogonium*.

Subsequently, the cytoplasm divides and collects around each of the

four nuclei forming four **zoospores.** At the time of germination the wall of the oospore bursts and zoospores escape being surrounded by the vesicle. Finally, the vesicle disappears, and the zoospores swim freely in water. Subsequent development of the zoospore and the formation of the vegetative filament take place in the usual way.

Some species may regularly form **parthenospores (aboospores)** developed from unfertilized eggs. The parthenospores completely fill up the entire cavity of the oogonium and possess walls like zygotes.

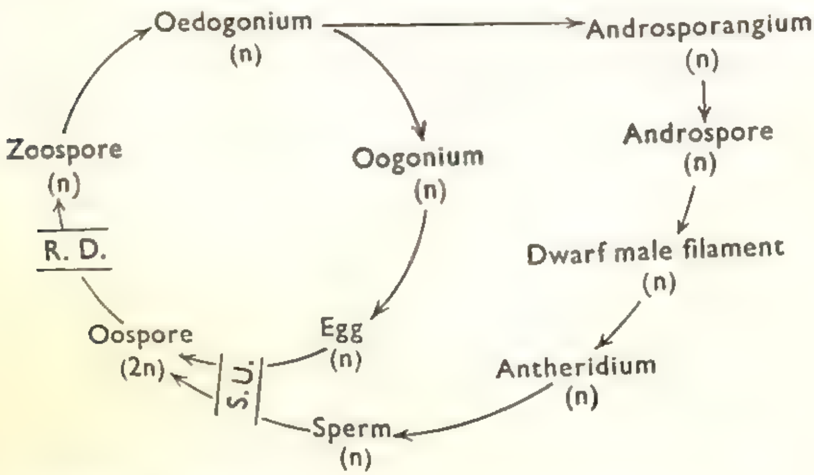


Fig. 54 . Life cycle of a *nannandrous* sp ecies of *Oedogonium*.

ORDER 7. CONJUGALES

Unicellular or colonial (generally filamentous) with elaborate chloroplasts ; motile gametes unknown ; reproduction by vegetative cell division or by conjugation of amoeboid gametes ; exclusively freshwater.

SPIROGYRA

(Fam. ZYGNEMATACEAE)

Spirogyra represents one of the commonest freshwater green algae. It is usually found as a free-floating inhabitant of the stagnant water of ponds, tanks, ditches, etc., forming a green slippery mass.

Occasionally, it is found in running streams and springs, where it attaches itself to rocks or other objects by means of holdfasts or haptera. These develop as much-branched outgrowths of the lateral walls of the vegetative cells.

The common Indian species of *Spirogyra* are *S. adnata*, *S. affinis*, *S. biformis*, *S. crassa*, *S. elongata*, *S. exilis*, *S. inflata*, *S. neglecta*, etc.

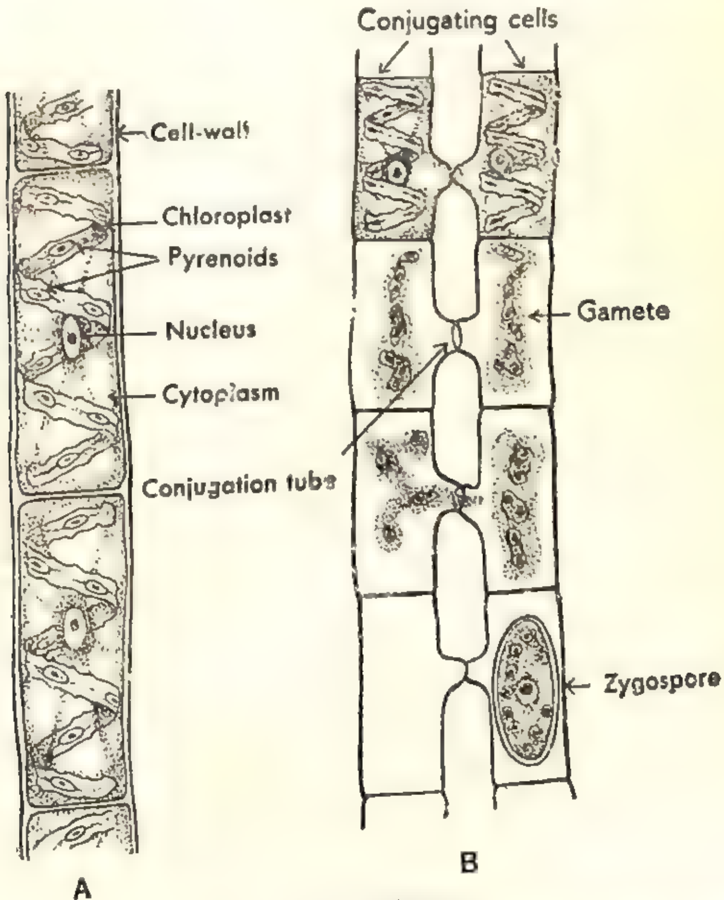


Fig. 55. *Spirogyra*.
A, Portion of the filament showing vegetative cells; B, Successive stages in scalariform conjugation.

Vegetative body

The vegetative body of the plant consists of an unbranched filament, a number of which are intermingled with one another into a mass, commonly called the **pond scum.** A filament is composed of a single row of cylindrical cells joined end on end, usually in

the case of free-floating species, without any distinction into base and apex. The filament increases in length by ordinary cell division and by subsequent growth of individual cells, each of which is equally capable of further divisions. The lateral walls of the cells are three-layered, the inner two of cellulose and the outermost one of pectose of variable thickness. The middle lamella (cross wall) is made up of pectose with a layer of cellulose on either side. It is simple in dwarf and shorter filaments, but **replicate** (with annular ingrowth of cellulose layers) in slender and narrower ones. The protoplasm is granulated, vacuolated and in the form of a primordial utricle. The nucleus, containing a distinct nucleolus, lies in a sheath of cytoplasm at the centre and is suspended in the vacuole by means of conspicuous cytoplasmic strands, extending from the periphery of the protoplasm. The most remarkable elements in a cell are a varying number (1—7) of ribbon-shaped chloroplasts, peripheral in location and running usually spirally throughout the length of the cell. Each chloroplast has smooth or serrated lateral margins and a varying number of dense, highly refractive, colourless proteinaceous bodies, the **pyrenoids** (in regular axile series or scattered), which form the seats of deposition of starch grains as reserve food.

Reproduction

Spirogyra reproduces by the vegetative and sexual methods only.

The vegetative multiplication takes place by the breaking down of the filament, either due to the softening of the middle lamella between two adjacent cells or by its accidental breaking. The filaments, thus formed, may be unicellular or multicellular and each such fragment, by repeated cell divisions, gives rise to a new plant.

In spring the plant reproduces sexually by **conjugation,** *i.e.*, by the union of two similar or morphologically identical gametes, which are formed by the protoplasts of ordinary vegetative cells. Each of these vegetative cells is called a **gametangium,** and its undifferentiated, uninucleate protoplast is called a **gamete.**

In heterothallic species, conjugation takes place between the cells of two different filaments. At first the two filaments lie in close proximity with each other throughout their entire lengths, and there is a secretion of a common gelatinous envelope around

them. In this position, short transverse papillae are developed from the walls of cells of the adjacent filaments. These papillae come in contact by corresponding pairs and grow further, thus pushing the original filaments apart. Finally, the end-walls of these outgrowths are dissolved away and the cells are thus connected by an open tube (**conjugation tube**). By this time the protoplasts (gametes of the two conjugating cells) have begun to contract, and after the formation of the conjugation tube, the protoplast (male gamete), which began its contraction earlier, migrates through the conjugation tube and unites with the other protoplast (female gamete) there, forming the dark-coloured zygote, called **zygospore,** which secretes a wall around it. The wall formed around the zygospore is a three-layered resistant structure, of which the middle layer is coloured and shows ornamentations. In exceptional cases the chloroplasts contributed by the male gamete disintegrate. This type of conjugation is known as the **scalariform conjugation.**

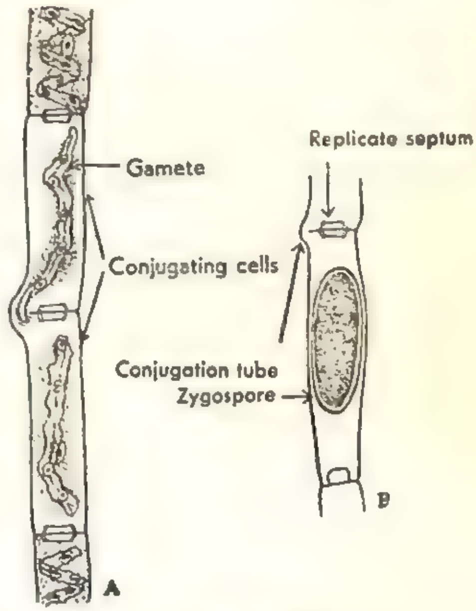


Fig. 56. *Spirogyra.*
A—B, Stages in lateral conjugation.

In homothallic species conjugation takes place between the adjoining cells of the same filament. This is termed the **lateral conjugation.** The zygospore may be globular, ellipsoidal, or cylindrical with obtuse ends, rarely flattened and discoid in shape.

Though the gametes are morphologically identical, the migration of one of them into the other gametangium proves them to be physiologically or biologically differentiated. As the zygospore attains maturity, there is a reduction division of its fusion nucleus forming four haploid nuclei, of which three undergo disintegration. After a considerable period of rest the zygospore germinates, its two outermost wall layers rupture, while its innermost layer (sur-

rounding the protoplast) emerges in the form of a tubular outgrowth. By the formation of a transverse septum a cell is formed at the distal end, which by successive new divisions, gives rise to a *Spirogyra* filament.

Fig. 57. *Spirogyra*. A germinating zygospore.

It has been observed that during scalariform conjugation usually all the cells of one filament may produce gametes of one sex, so that after conjugation there is migration of all the gametes of one filament (may be regarded as the male) to the cells of other filament (female) forming zygotes there. But, it may so happen that each filament may contain both male and female gametes so that cross conjugation may occur forming zygotes in both the filaments. It should be noted that all the cells of a filament may be fertile or there may be regular alternation of fertile and sterile ones.

When conjugation fails, the gamete surrounds itself with a thick wall and forms a parthenospore or azygospore, which after a period of rest germinates into a new plant.

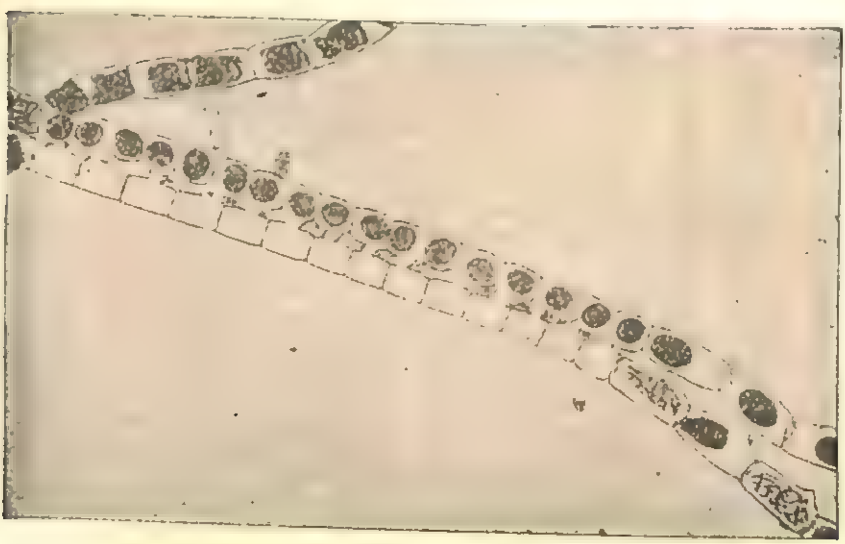


Fig. 58. Photomicrograph of *Spirogyra* showing scalariform conjugation.

ZYGNEMA

(Fam. ZYGNEMATACEAE)

Zygnema is another widely distributed, freshwater, green alga which occurs in much the same type of habitats as does *Spirogyra*.

The common Indian species of *Zygnema* are *Z. amplum*, *Z. gangeticum*, *Z. giganteum*, *Z. gorakhporense*, *Z. indica*, *Z. iyengari*, *Z. melanosporum*, *Z. sphaerica*, etc.

Vegetative body

The thallus, like *Spirogyra*, is an unbranched filament without any distinction into base and apex. A filament consists of a single row of similar cylindrical cells, usually having lengths slightly greater than breadths; occasionally, the cell may be 2-5 times as long as broad. Holdfasts or haptera are rarely formed. The wall structure is much the same as that in *Spirogyra*, but the outermost pectose layer rarely becomes thick. The transverse walls are never replicated. The protoplast is uninucleate, and the nucleus is embedded in a broad strand of cytoplasm connecting two chloroplasts on either side; this band occupies the longitudinal axis of the cell. Each chloroplast is stellate or star-shaped with a prominent pyrenoid at its centre, and it may have numerous delicate strands extending towards the periphery of the cytoplasm. The filament increases in length by cell divisions and subsequent growth of the individual cells. Prior to the cell division, the nucleus divides mitotically into two, so that after cytokinesis, each daughter cell receives one daughter nucleus and a chloroplast of the parent cell, the former lying lateral to the latter. Subsequently, the chloroplast with its

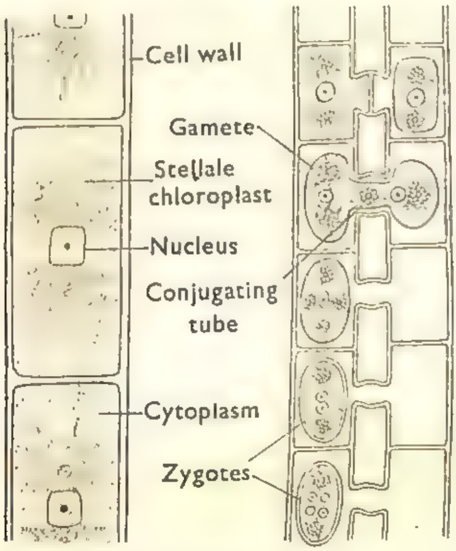


Fig. 59. *Zygnema*.
Part of a filament (on the left); Successive stages in conjugation and formation of zygospores (on the right).

pyrenoid divides into two and the nucleus migrates and occupies a position midway between the two daughter chloroplasts.

Reproduction

Zygnema reproduces by vegetative and sexual methods.

The vegetative reproduction usually takes place by the accidental breaking of the filament and never due to the softening of the cross wall of the adjacent cells

Most species of *Zygnema* reproduce sexually, in the spring, by the process of **conjugation.** Conjugation is usually scalariform, but lateral conjugation is not of rare occurrence. The process of scalariform conjugation is much the same as that in *Spirogyra*. The gametes of one filament (male) become active, amoeboid and migrate through the conjugation tubes to the gametes of the other filament (female), unite and form zygospores. But in some species both the gametes become amoeboid, migrate towards each other, fuse in the conjugation tube and form a zygospore there.

After gametic union, the zygote is invested by a wall, which becomes three-layered at maturity (a thin inner layer of cellulose, a median layer of cellulose which is often chitinized, and a thin outer layer of cellulose or pectose). The colouration and ornamentation are restricted to the middle layer, as in *Spirogyra*. The zygotes, at maturity, are finally liberated by the disintegration of the gametangial wall or of the wall of the conjugation tube, and usually undergo a period of rest for several months. With the advent of the following spring the zygote germinates, and prior to this germination there is a reduction division of the zygote nucleus forming four haploid nuclei, of which three disintegrate. During germination the two

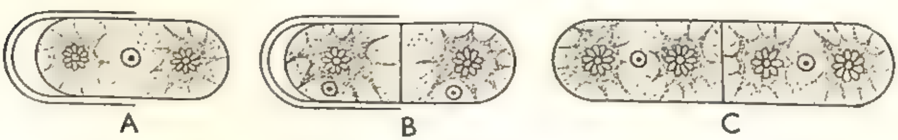


Fig. 60. *Zygnema*.
A—C, Stages in the germination of the zygote.

outer walls of the zygote rupture and the protoplast being still enclosed by the innermost wall-layer may partially or wholly escape from the ruptured walls. This protoplast by repeated divisions gives rise to a new filament.

When conjugation fails, a gamete may form azygospore or parthenospore. But these are not produced in abundance in the genus.

COSMARIUM

(Fam. DESMIDIACEAE)

Cosmarium and other members of the Family Desmidiaceae are commonly known as "desmids". They are all inhabitants of freshwater and are found sparingly intermingled with other free-floating algae everywhere.

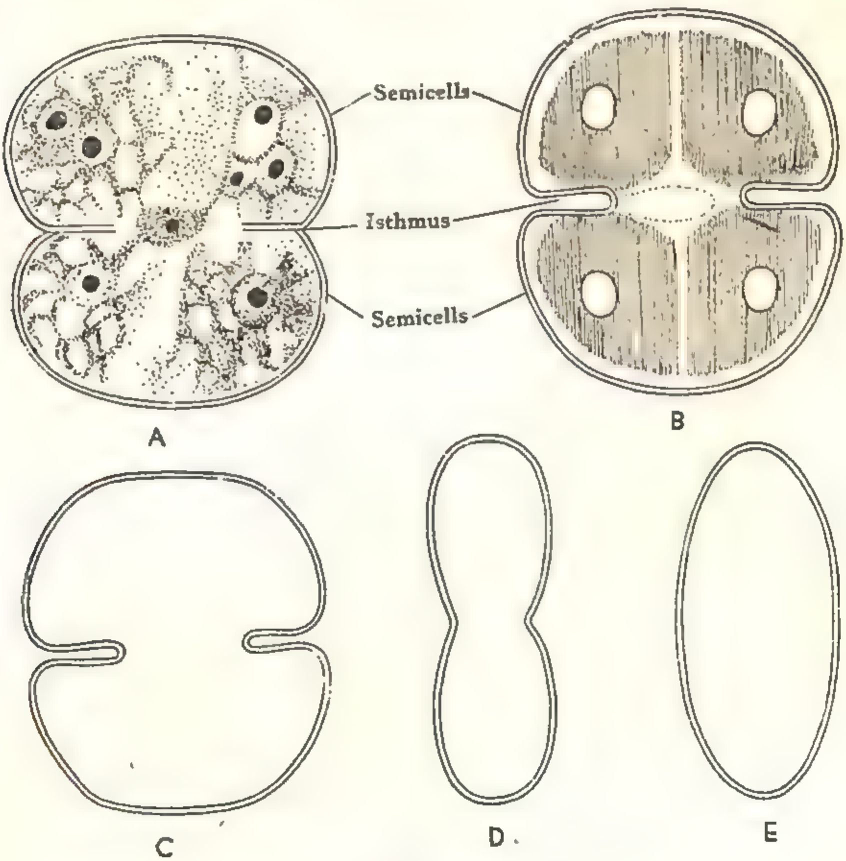


Fig. 61. *Cosmarium.*
A, A vegetative cell in section; B, Diagrammatic representation of the vegetative cell; C—E, Front, side and vertical views of the vegetative cell. (*Diagrammatic*).

The common Indian species of *Cosmarium* are *C. abruptum*,

C. aequale, *C. americanum*, *C. apertum*, *C. aversum*, *C. bengalense*, *C. barrackporeanum*, *C. biobeonicum*, *C. coloratum*, *C. deacuminatum*, *C. dubium*, *C. ellipsoidale*, *C. exile*, *C. forceps*, *C. lacustre*, etc.

Vegetative body

Cosmarium is a unicellular genus which may be easily recognized in having small compressed cells, each being divided by a

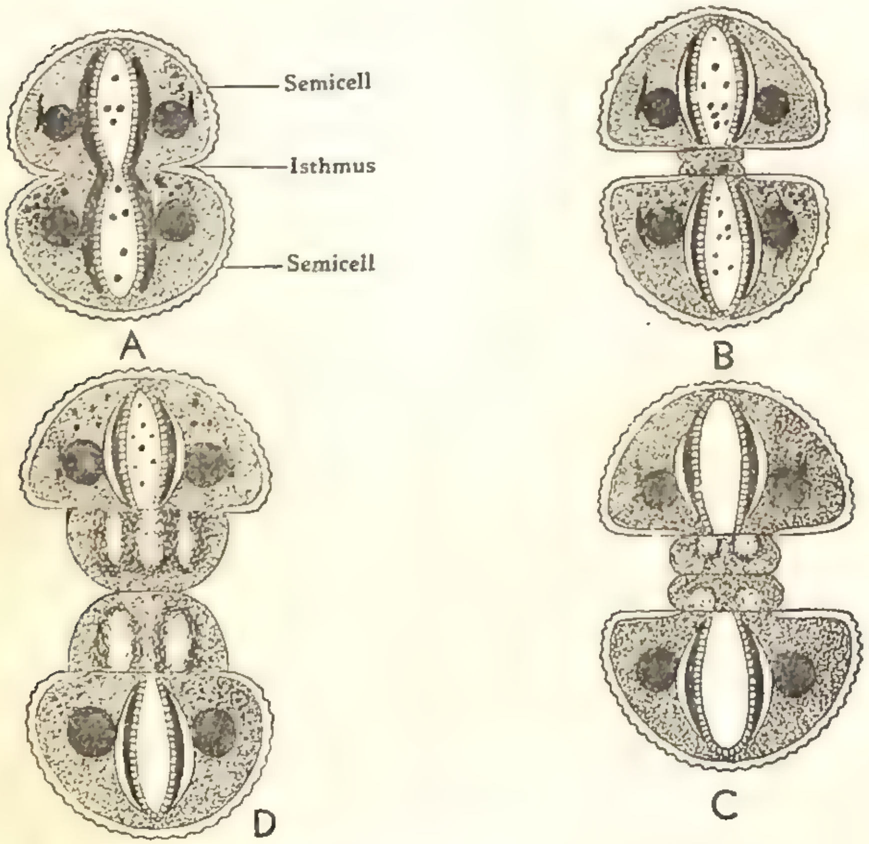


Fig. 62. *Cosmarium.*
A, A vegetative cell; B—D, Vegetative reproduction showing formation of daughter cells.

conspicuous median constriction (**sinus**) into two distinct symmetrical halves (**semi-cells**), united together by a comparatively narrow connecting zone (**isthmus**). Its species are distinguished partly from such characters as cell shape, ornamentation of the wall, etc. Each cell should be examined in front, side and vertical

views. In front view the semi-cells may be circular, elliptical, reniform or sub-quadrangular in shape, whereas in vertical view they are usually elliptical in outline. In side view the semi-cells, in most cases, appear more or less circular in outline.

The cell wall in *Cosmarium* is never spiny, and it consists of three concentric layers : (1) an innermost thin cellulose layer, (2) a somewhat thicker median layer consisting of cellulose and pectic compounds, and (3) an outer thick or thin layer of gelatinous sheath made up of pectose. Excepting at the isthmus region the inner two layers are perforated by vertical pores, being usually arranged in a definite pattern and are distributed all over the semi-cells, or may be localized. The outer wall is usually smooth, but may sometimes appear somewhat granular.

The protoplast contains a single nucleus which always lies at the isthmus and is sometimes connected with the string-like projections of the chloroplast. Each nucleus contains a conspicuous nucleolus and well-defined nuclear reticulum.

Usually, there is only one chloroplast in each semi-cell, but sometimes two or four chloroplasts may be present. Each chloroplast contains a single pyrenoid and is provided with four to several radiating plate-like extensions.

The cells of *Cosmarium* exhibit movement which consists in a series of jerks. This is due to the secretion of gelatinous material through the vertical pores.

Reproduction

Cosmarium reproduces both by vegetative and sexual methods.

The vegetative method of reproduction takes place by the method of cell division and two daughter cells are formed from the parent cell. During the process the nucleus first divides into two daughter nuclei and the isthmus slightly elongates. A transverse wall is formed across the isthmus in such a way that each semi-cell receives one daughter nucleus. The portion of the isthmus, attached to each semi-cell, now enlarges and forms a new semi-cell, and in this way two daughter cells are formed. The daughter cells remain attached to each other for some time but finally separate. Thus, it is evident that of the two semi-cells, one semi-cell is younger than the other, which belongs to the parent cell. The newly formed semi-cell receives a chloroplast with a pyrenoid by the division of the pre-

existing one of the other semi-cell. Sometimes pyrenoid may be formed *de novo* in the newly formed chloroplasts.

Sexual reproduction is **isogamous** and consists in the union of two identical gametes, produced usually by two mature individuals. Conjugation may also take place between two newly formed sister

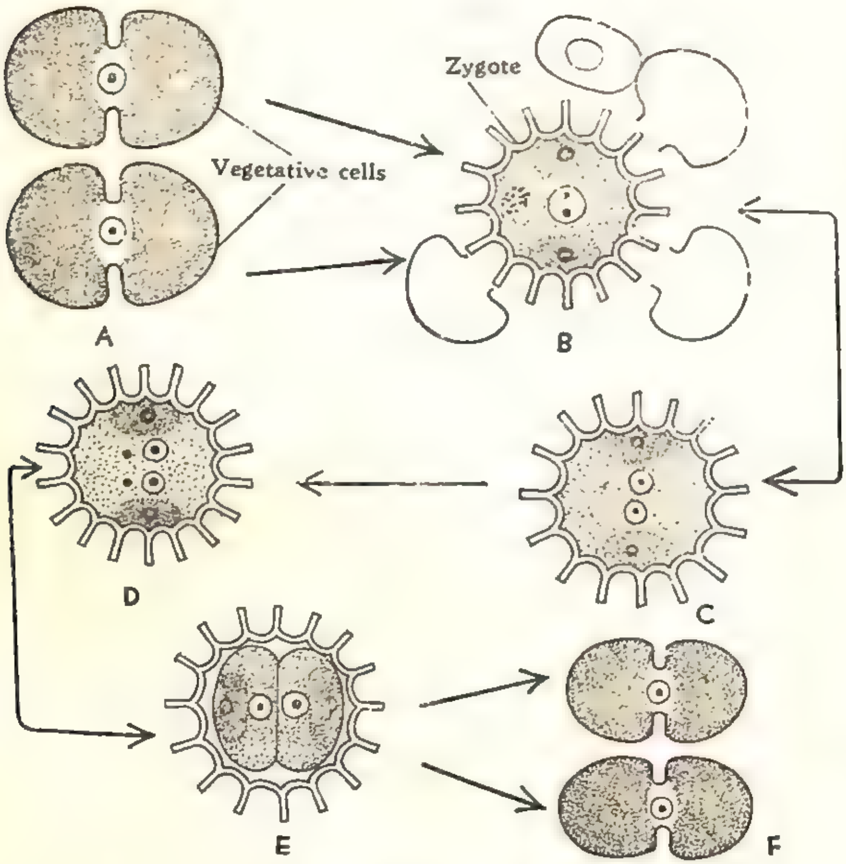


Fig. 63. *Cosmarium*.
Stages in sexual reproduction, and formation and germination of the zygote.

cells. During conjugation, usually two mature cells come to lie in contact with each other and become surrounded by a common gelatinous sheath secreted for the purpose. The protoplast of each cell functions as a gamete. Each cell then breaks at the isthmus and the gamete escapes. The two gametes, thereupon, fuse outside and after secreting a thick wall around it form a somewhat

globose or angular zygospore. Its wall may be smooth, papillate or spiny. The zygospore, after a considerable period of rest, germinates. The fusion nucleus undergoes a reduction division forming four haploid nuclei, of which two degenerate and the remaining two are functional. The protoplasm then divides into two equal halves, each receiving one functional nucleus and a chloroplast. Each daughter protoplast finally develops into a vegetative cell, which is liberated by the rupture of the zygote wall.

When conjugation fails, azygospores or parthenospores may be formed. The parthenospore, during germination, contains three degenerating nuclei and one functional nucleus, which, by division, gives rise to the nuclei of the two resulting vegetative cells.

CLOSTERIUM

(Fam. DESMIDIACEAE)

Closterium is one of the largest genera of planktonic desmids. It is widely distributed throughout the world being altogether restricted to freshwater of small ponds, margins of rocky lakes and other bodies of water which are not alkaline.

The common Indian species of *Closterium* are *C. abruptum*, *C. anastomosum*, *C. costatum*, *C. exiguum*, *C. intermedium*, *C. legumen*, *C. khasianum*, *C. manipurense*, *C. striatum*, etc.

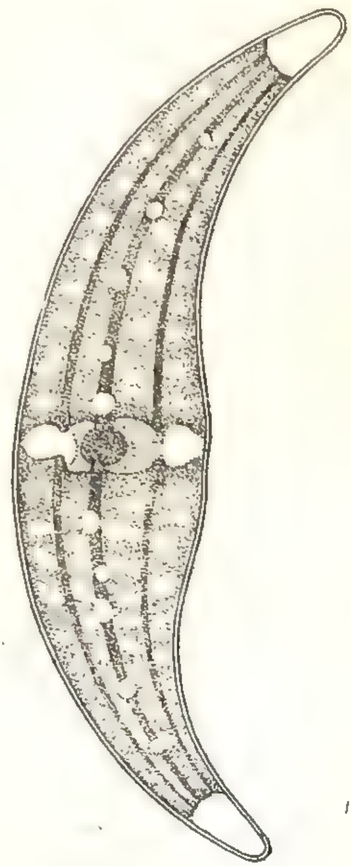


Fig. 64. *Closterium*. An entire plant.

Vegetative body

The body of *Closterium* is strictly unicellular, which is elongated or somewhat lunate without any median constriction, and attenuated at both ends. The cell wall is provided with delicate pores and in most

cases with longitudinal striations. It is mainly made up of cellulose and often appears yellowish-brown in colour due to impregnation with iron compounds. The cell wall consists of two halves, one belonging to the older and the other to the younger generations. They fit so closely and firmly that they are not easily recognizable in living conditions but becomes separated after death or during conjugation. The protoplast contains two chloroplasts, one within each half of the cell wall and usually with a few pyrenoids. The chloroplasts are either entire or they are provided with radiating longitudinal ridges. The nucleus lies embedded in a mass of cytoplasm and is connected with the two chloroplasts by means of thin cytoplasmic strands. At the attenuated ends (**poles**) of each cell there is a conspicuous vacuole in which are embedded one or more crystals of gypsum salts.

Reproduction

Closterium reproduces vegetatively as well as by the sexual method.

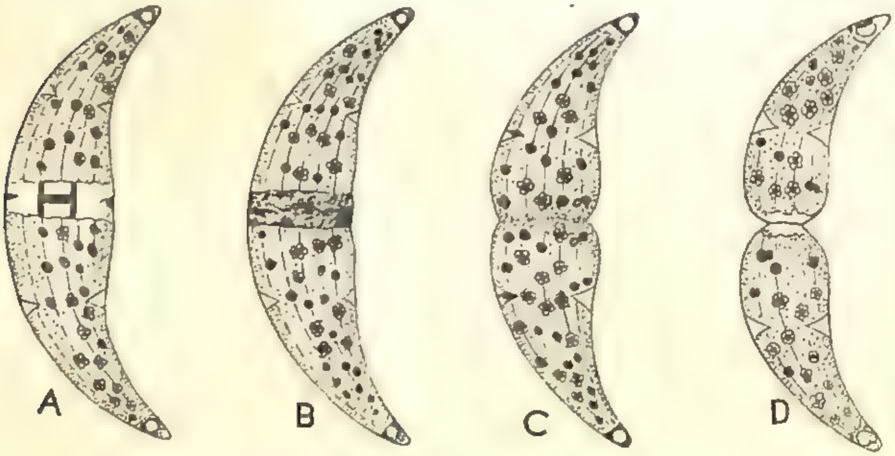


Fig. 65. *Closterium*.
A—D, Stages in vegetative reproduction.

During vegetative reproduction there is a transverse division of the pre-existing nucleus and the two chloroplasts. It is very peculiar that in this case the dividing wall is not formed in the middle of the cell but a little away from the centre and within the younger half wall of the cell.

Sexual reproduction takes place by **conjugation** of amoeboid gametes from two conjugating cells. In some cases, a rudimentary conjugation tube may be formed between them; in others, sister cells probably conjugate. In most cases, the cell wall breaks in the middle region (isthmus) and its protoplast escapes as an amoeboid gamete, which, on finding its mate, unites with it and forms a spherical, ovoid or quadrangular zygote (zygospore) with thick or ornamented walls. After the resting period the zygote germinates, its nucleus divides reductionally forming four daughter nuclei, of

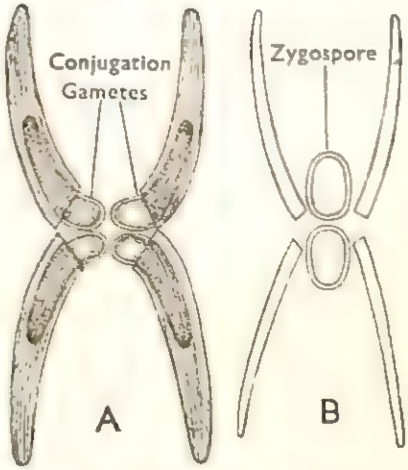


Fig. 66. *Closterium*.
A—B, Stages in sexual reproduction.

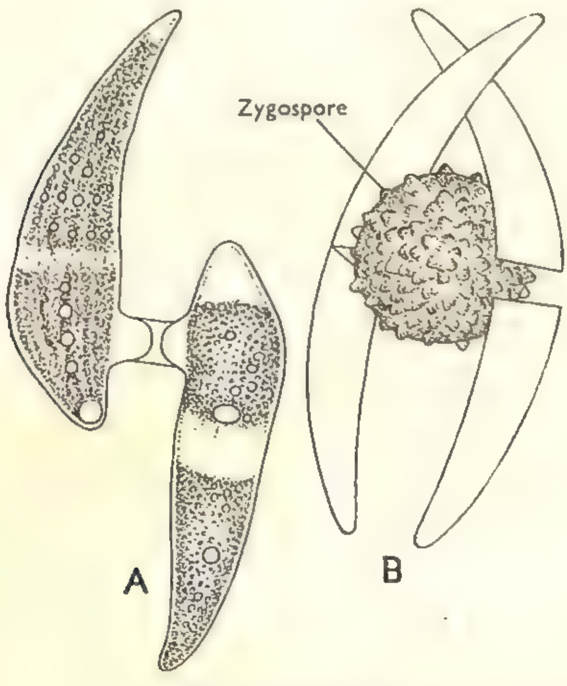


Fig. 67. *Closterium*.
A—B, Stages in formation of zygospore.

which two degenerate. This is followed by the division of the protoplast, each of which contains a single chloroplast, a functional and a disintegrating nucleus. The daughter protoplast sooner or later surrounds itself with a cell wall and assumes the shape characteristic of the genus.

ORDER 8. **SIPHONALES**

Filamentous ; without septa or elaborately differentiated ; all parts coenocytic ; chloroplasts numerous and discoid ; sexual reproduction mainly isogamous, sometimes oogamous, unknown in many cases ; mostly marine.

CAULERPA

(Fam. CAULERPACEAE)

Caulerpa is a green alga, the species of which are mostly distributed in the tropical seas. They occur generally in shallow and calm waters being usually rooted in sand or mud. Quite a large number of species, however, grow attached to rock or coral reefs and may sometimes also occur as epiphytes on roots of mangrove plants.

The common Indian species of *Caulerpa* are *C. clavifera, C. scalpeldiformis*, etc.

Vegetative body

The thallus is one-celled and shows higher morphological differentiation. It is differentiated into a prostrate, more or less branched, cylindrical, rhizome-like portion, which bears on its underside root-like rhizoids and erect cylindrical branches or the **leafy shoots** on its upper side. Thus, the external form is comparable to that of a vascular plant with a creeping rhizome. The upright branches bear lateral outgrowths or **assimilators,** which are usually flattened, but the forms of the shoots may vary from species to species, often resembling the cacti, the mosses or the lycopods. The entire unicellular body is a branched coenocyte without transverse septa. The cytoplasm is continuous lying internal to the cell wall, and contains

numerous nuclei and disciform chloroplasts without pyrenoids. There is a single central vacuole which runs throughout the entire length of the plant.

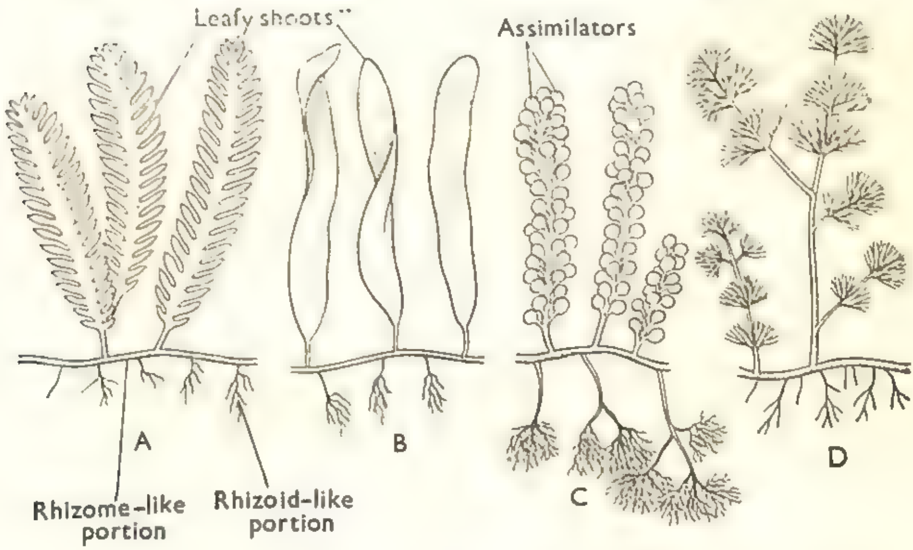


Fig. 68. *Caulerpa*.
A—D, Portions of the vegetative bodies of different Indian species of the same.

The cell wall is comparatively thick and is provided with numerous transverse and longitudinal skeletal strands or **trabeculae** traversing the central cavity of the thallus. These trabeculae are most strongly developed in the rhizomatous portion, but becoming fewer and fewer in the assimilators and may be poorly developed in the rhizoids or altogether absent. As the thallus gradually becomes older due to the deposition of successive strata of wall materials, the lateral wall as well as the trabeculae become distinctly stratified in appearance. The wall is composed of callose, pectin, pectic acids and pentose, cellulose being entirely absent. The rigidity of the plant is maintained due to the turgidity of the thallus and thickness of the cell wall.

Reproduction

Caulerpa reproduces by vegetative, asexual and sexual methods.

During vegetative reproduction the older parts of the rhizome gradually die away, thereby separating the erect shoots. These

detached shoots are dispersed by the waves and possess the remarkable power of producing new plants when affixed to any suitable substratum. In this way rapid multiplication of the plant is effected.

Several species of *Caulerpa* reproduce asexually by the production of **zoospores**, but the details of the zoospore-formation and their behaviour are very little known. Zoospores may be produced from any portion of the leafy shoots or rarely from the rhizome. After their formation, the zoospores appear to remain in reticulate masses within the cell and numerous papillate outgrowths are developed on the surface of the thallus. These papillae are known as **extrusion papillae,** through which zoospores are liberated in a mass of mucilagenous matter in such an enormous quantity that the water surrounding the thallus appears green for the time being. Each zoospore is biflagellate, pyriform in shape and possesses a single curved chloroplast without any pyrenoid. In many species it disorganizes after liberation.

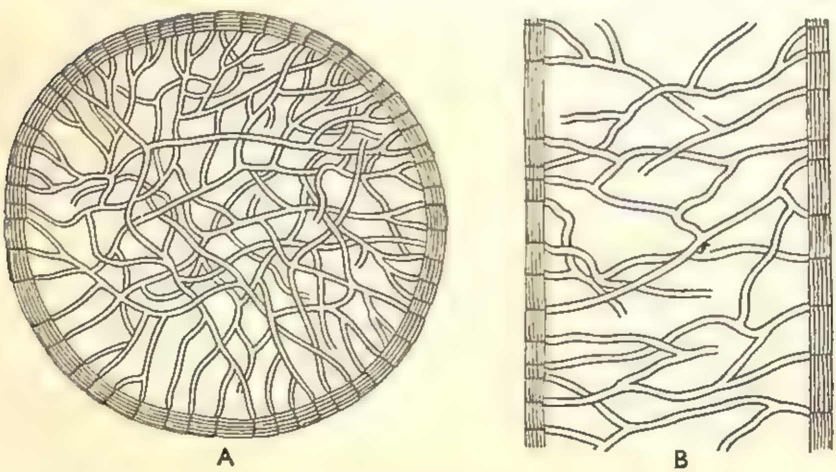


Fig. 69. *Caulerpa*.
A, Trabeculae in rhizomatous portion; B, The same in an assimilator.

Sexual reproduction by the union of gametes has been reported in several oriental species. In one of them, *Caulerpa clavifera*, a heterothallic plant, reproduction has been shown to be anisogamous.

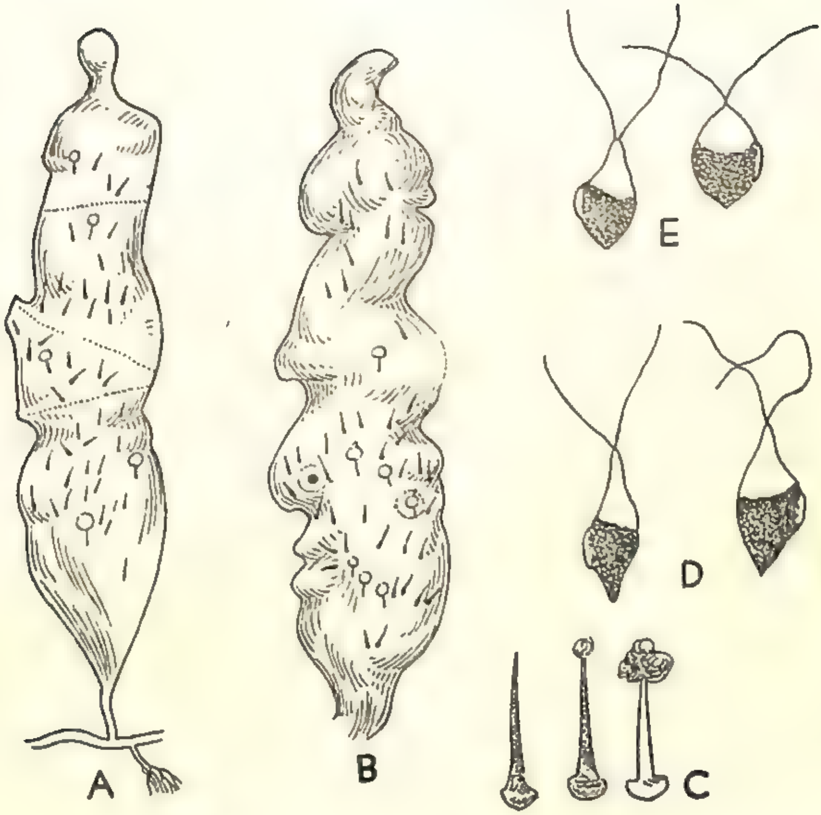


Fig. 70. *Caulerpa*.
A—B, Formation and liberation of zoospores through extrusion papillae on the surface of leafy shoots; C, Development of extrusion papillae; D—E, Zoospores.

VAUCHERIA

(Fam. VAUCHERIACEAE)

Vaucheria is an inhabitant of freshwater, though a few marine species are not uncommon. Some are terrestrial and may grow on bare moist soil or in ploughed fields forming extensive interwoven felty sheets.

The common Indian species of *Vaucheria* are *V. aversa*, *V. clavata*, *V. orientalis*, *V. ornithocephala*, *V. submarina*,, *V. uncinata*, *V. sessiles*, etc.

Vegetative body

The thallus consists of a sparingly branched tubular, coenocytic filament having no cross walls excepting at the reproductive regions. They are attached to the substratum by means of rhizoid-like branches.

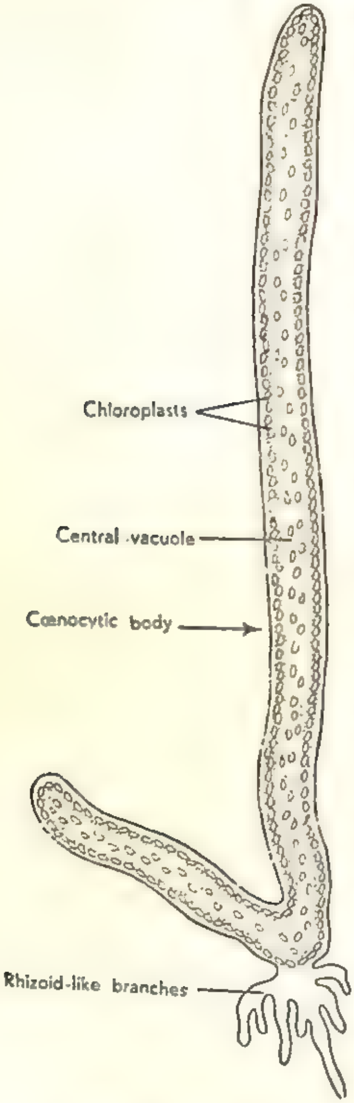


Fig. 71. *Vaucheria.* An entire plant.

The growth of the thallus is restricted to the apices of the branches. The coenocytic thallus, when injured, may develop transverse septa blocking the injured portion. The cell wall is thin and consists of an inner layer of cellulose and a pectose layer external to it. Just within the cell wall there is a thin layer of cytoplasm surrounding a large central vacuole which runs, without interruption, throughout the entire length of the thallus. Embedded in the peripheral layer of cytoplasm are numerous nuclei and chloroplasts, the former lying towards the inner face and the latter towards the outer face of the cytoplasm. The chloroplasts are without pyrenoids and are either circular or elliptical in outline. Food reserves are stored as oil under natural condition, but when continuously illuminated, starch may be formed instead.

Reproduction

Vaucheria reproduces both asexually and sexually.

There are various methods of asexual reproduction. Typically, the method is by means of large **multiflagellate zoospores,** each being formed singly within a club-shaped zoosporangium developed at the apex of a branch. During the development of a zoosporangium the distal end of a branch forms a club-shaped swelling, and a portion

of the protoplast is cut off by its transverse division just a little behind the branch apex. This portion of the protoplast is finally separated by a transverse septum and forms the zoosporangium containing a multinucleate protoplast. This protoplast then slightly contracts, the nuclei and chloroplasts change their positions, a pair of flagella develops external to each nucleus and a multiflagellate zoospore is formed. At maturity, the apex of the zoosporangium

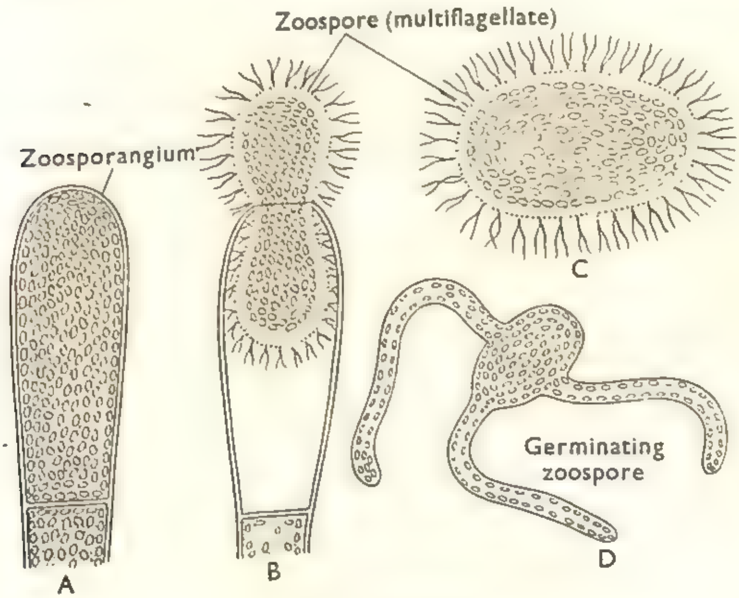


Fig. 72. *Vaucheria.*
A—C, Asexual reproduction showing formation and liberation of zoospores; D, A germinating zoospore.

softens forming a small pore through which the zoospore squeezes its way and finally swims freely but slowly in water. After a short period of activity, the zoospore comes to rest, withdraws its flagella, and secretes a wall around it. The germination starts immediately by the formation of one or more tubular outgrowths which finally develop into a new thallus.

In species of *Vaucheria*, growing on damp soil in green houses, the entire protoplast of the sporangium, instead of producing a zoospore, may develop into a thin-walled **aplanospore** or a thin-walled **akinete.** This aplanospore is liberated by the rupture of the sporangial wall, and on germination, gives rise to a thallus. The akinete becomes separated from the thallus or germinates *in situ.*

Sometimes due to scarcity of water, the entire protoplast of *Vaucheria* undergoes transverse divisions into short segments, around each of which a thick wall is secreted. These are thick-walled aplanospores (**hypnospores**), which either germinate directly or the protoplast of each divides into a number of thin-walled **cysts.** At maturity, the protoplast of each cyst escapes in an amoeboid fashion and eventually comes to rest, rounds up, secretes a wall around it, and germinates into a new thallus.

All species of *Vaucheria* reproduce sexually and are oogamous.

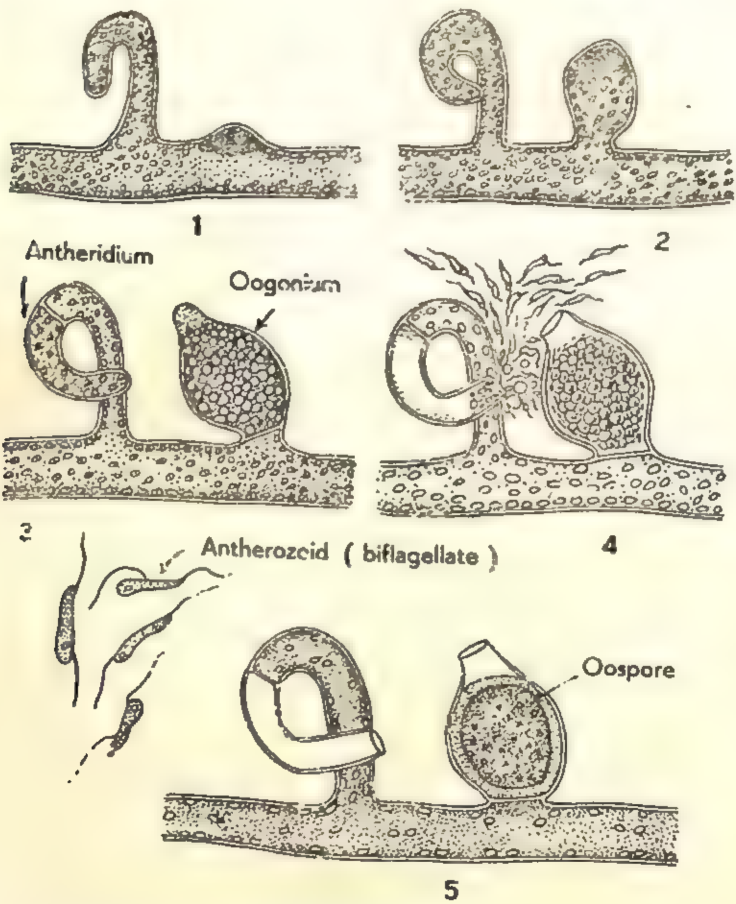


Fig. 73. *Vaucheria.*
1—5, Development of sex organs and progress of sexual reproduction.

They are mostly homothallic, but a few marine species are heterothallic.

In homothallic species both antheridia and oogonia develop, either side by side on the same filament, or on a common lateral branch, or on different branches of the same thallus lying quite close to each other. They develop either simultaneously or the antheridia may develop earlier.

The antheridium, which is usually an elongated, hook-shaped structure, develops at the apex of a short lateral branch. During its development the apical portion of the lateral branch becomes densely filled with multinucleate protoplasm with a few chloroplasts. This denser portion is separated from the rest of the protoplasm by a transverse cleavage and is soon followed by the formation of a septum. The cell, thus cut off, is an antheridium. Its protoplast is eventually divided into several uninucleate segments, each of which is finally metamorphozed into a spermatozoid with two terminal flagella of equal lengths. At maturity, the spermatozoids are, in most cases, liberated in the surrounding water through an apical pore formed by the gelatinization of the apex of the antheridium.

Usually, simultaneous with the formation of the antheridium oogonial development begins, and there is an accumulation of colourless multinucleate mass of cytoplasm (called **wanderplasm**) in the main filament near about the base of the antheridial branch. This is followed by the formation of a lateral bulge into which the wanderplasm migrates. As the bulge increases in size, numerous nuclei and chloroplasts also accumulate within it and ultimately the oogonium is formed, which is cut off from the main filament by the formation of a septum. When the oogonium is situated at the apex of a branch, it starts its development as an apical swelling which is finally cut off from the rest of the branch by the formation of a transverse septum. A mature oogonium contains a uninucleate egg. There is a great diversity of opinion as to the formation of the uninucleate egg. According to some, the uninucleate condition is obtained by the degeneration of all the nuclei excepting one; others hold that all the nuclei, but one, migrate out of the oogonium before the formation of the transverse septum. There are still others who hold that the differentiation of the ovum and fertilization take place prior to the formation of the transverse wall. At maturity, a **beak** is formed at the end of the oogonium and it undergoes gelatinization forming an apical pore through which a droplet of gelatinous material exudes.

The spermatozoids, liberated from the neighbouring antheridia, swim towards the oogonium and accumulate round the droplet. Usually, several spermatozoids enter through the apical pore of the oogonium, but only one fertilizes the ovum. The nuclei of the two gametes, following union, soon after fuse near about the apical pore, but the fusion nucleus finally migrates towards the centre of the zygote. Following fertilization the zygote secretes a thick wall, often consisting of 3-7 layers, around itself and its protoplasm becomes rich in oil reserves. This zygote, after a period of rest for several months, germinates into a new filament. It has been held by the algologists that the division of the zygote nucleus, prior to its germination, is probably reductional.

Systematic position

The systematic position of *Vaucheria* is a much debated point. Workers like Fritsch and others have placed it with all the other oogamous siphonaceous green-coloured algae under the Class Chlorophyceae. Chadefaud was the first to question this position of *Vaucheria*, and formally placed it in the Order Heterosiphonales belonging to the Class Xanthophyceae. It was so placed because of the absence of starch in *Vaucheria* and the special colour of its chomatophore. Since then, additional proofs have been forthcoming from the works of Strain (1948), Koch (1951) and other workers to show that *Vaucheria* decidedly belongs to the Xanthophyceae. These include the following points mainly : (*a*) the pigments in the chromatophores of *Vaucheria* are those typically found in the Xanthophyceae, (*b*) the two xanthophylls, which are found only in the Siphonales, are lacking in *Vaucheria*, and (*c*) of the two equal-sized flagella borne anteriorly by an antherozoid, one is of the tinsel type and the other of the whiplash type.

BRYOPSIS

(Fam. BRYOPSIDACEAE)

Bryopsis is a marine alga, mainly distributed in the warm tropical seas, but a few of them may be found in cold water also during spring and early summer.

Vegetative body

The vegetative body of *Bryopsis* is a coenocytic thallus, which can be differentiated into several parts. There is a sparsely branched, horizontally growing rhizome-like portion, remaining attached to the substratum by rhizoids. This portion is supposed to be perennial. From this rhizomatous body there appear some erect axes or branches, which are pinnately branched, and the pinnules in their

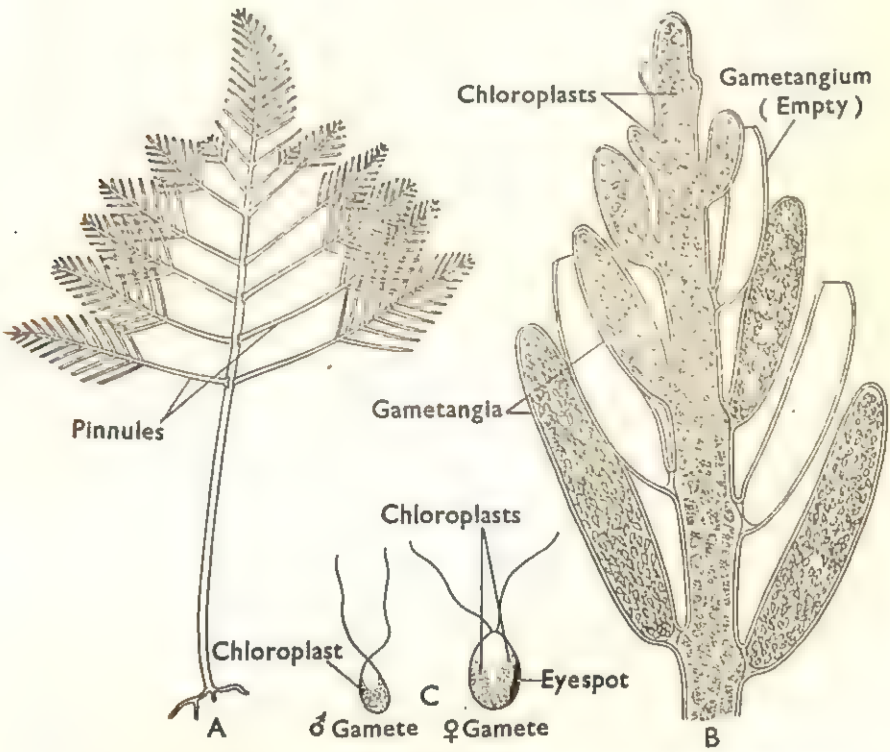


Fig. 74. *Bryopsis*.
A, The plant body; B, A portion of the plant body (magnified) showing gametangia; C, The two types of gametes.

turn may again be similarly branched. It is not definitely known whether these erect branches are perennial or annual. In the majority of species the pinnules are arranged on the erect axis in two vertical rows, but in some cases these are developed on all sides of the axes. The fully mature pinnules continually fall off, and consequently, the lower half of the axis is usually free from any appendage. The pinnules are arranged in an acropetal order, and

each one is provided with a constriction at the base at the point of its attachment with the main axis. The solitary cell of the plant body possesses a large continuous central vacuole. Lining this vacuole there runs a layer of cytoplasm containing numerous nuclei and many minute disc- to spindle-shaped chloroplasts. Usually each chloroplast contains a single pyrenoid. Though there is no septation within the body of the plant at an early stage, a cross wall is distinctly laid down at the time of abscission of an old pinnule.

Reproduction

Bryopsis reproduces vegetatively as well as sexually.

Under favourable conditions a pinnule, on being detached from the main axis, usually develops into a fresh thallus body. In one species of *Bryopsis* (*B. corticularis*), before the abscission of the pinnule, rhizoids develop at its base. In some cases rhizoids have been found to be developing from the apices of the pinnules, when the plants are kept in an inverted position or under very much diffused light.

Sexual reproduction takes place usually during the spring with the help of **biflagellate anisogametes.** The plants are heterothallic. The gametes are formed usually within the pinnules and occasionally within the axis also. A fertile pinnule thus behaves as a gametangium. The male and the female gametangia can be macroscopically differentiated, since the former are yellowish in colour, while the latter are dark green.

The development of a gametangium within a pinnule starts with the formation of a transverse wall at the pinnule base. The formation of this wall takes place in an identical manner as in the case of a mature vegetative pinnule ready for abscission. The nuclei within a gametangium divide reductionally and increase in number. By the cleavage of the protoplast a large number of biflagellate gametes are ultimately produced. The female gametes are about three times as large as the male ones. Each male gamete possesses a single chloroplast, while a female one has usually two chloroplasts and a very prominent eyespot. The gametes escape either through one or more minute apertures developed on the wall of the gametangium, or by the gelatinization of the apex. On liberation, the gametes swim vigorously for a few hours, and then unite and give rise to a zygote, which, in some cases, has been found to be quadriflagellate

for some time. Later on, it gets rounded off and enclosed by a wall. The zygote germinates directly, and very quickly gives rise to a new diploid plant. It is to be noted that the zygote nucleus does not divide reductionally, but equationally.

ORDER 9. **CHARALES**

Thallus well-differentiated into nodes and internodes ; internodes sometimes corticated ; branches of limited growth in whorls; chloroplasts numerous and discoid ; cells usually uninucleate ; reproduction vegetative and sexual with elaborate oogonia and antheridia ; germination of zygote indirect ; freshwater and brackish water.

CHARA

(Fam. CHARACEAE)

Chara, or "stonewort", is a submerged green alga which usually grows in freshwater ponds and lakes being attached to a muddy or sandy bottom, often forming an extensive sub-aquatic vegetation below the surface of water. Several species become incrustated with calcium carbonate.

The common Indian species of *Chara* are *C. zeylanica*, *C. fragilis*, *C. brachypus*, etc.

Fig. 75. *Chara*. A portion of the vegetative body.

Vegetative body

The thallus consists of an erect, branched axis being attached to the substratum by means of rhizoids. The rhizoids are branched filaments which may or may not have nodes and

internodes. The erect axis is distinctly differentiated into nodes and internodes. At each node there is a whorl of **branches of limited growth,** the **leaves.** The so-called leaf usually possesses 3-8 internodes. One or more **branches of unlimited growth** may also develop in the axils of these leaves. In some species, each internode consists of a single elongated cell which is many times longer than broad, but in most cases the internodal cell is **corticated,** *i.e.*, surrounded by a single layer of much smaller, vertically elongated cells. The axes grow by means of apical cells from which segments are cut off successively by transverse walls. Each of these segments divides transversely into two cells, the lower one of which enlarges to form a long internodal cell, and the upper one, by successive divisions, gives rise to the layer of nodal cells, to the lateral branches or to the rhizoids. The long internodal cell becomes covered over by a cortical layer consisting of longitudinal rows of cells formed by division of the basal cells of the leaves of the upper and lower nodes, the basal node of each leaf producing one **ascending initial** and one **descending initial.**

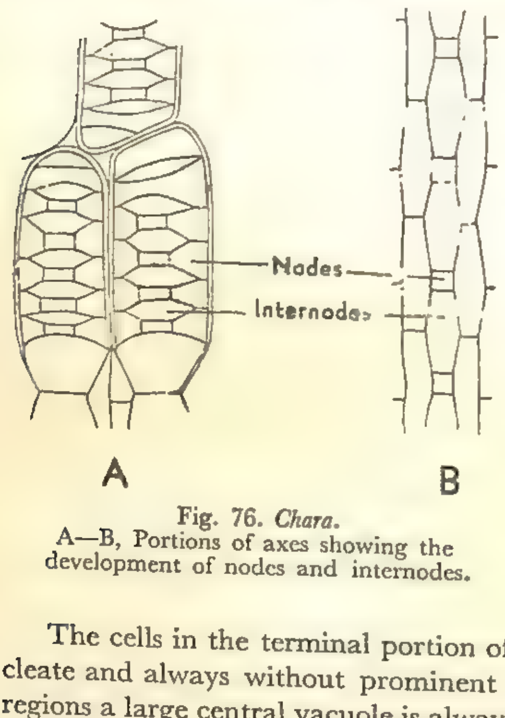


Fig. 76. *Chara.*
A—B, Portions of axes showing the development of nodes and internodes.

The cells in the terminal portion of a branch are always uninucleate and always without prominent vacuoles. But in the mature regions a large central vacuole is always present. In the latter case, the cytoplasm is in the form of a primordial utricle with innumerable small, ellipsoidal chloroplasts and a few comparatively large nuclei. The nuclei are more or less irregular in shape and increase in number by amitosis. The disposition of chloroplasts in the cytoplasm is vertically parallel, and they appear to be in spirally twisted files. The cytoplasm shows streaming movement and moves in longitudinal direction, so that, there is an ascending stream on one side and a descending one on the other.

Reproduction

Chara reproduces by vegetative and sexual methods. Zoospores are entirely lacking in them.

Vegetative reproduction is quite common and may be effected by the formation of special vegetative reproductive bodies, such as (*a*) **amylase stars,** which are star-shaped aggregates of cells densely filled with starch grains and developed in the lower internodes, (*b*) **bulbils** formed on the rhizoids, and (*c*) **protonema-like outgrowths** developed from the nodes.

Fig. 77. *Chara*. A portion of a "leaf" bearing nucule and globule.

Sexual reproduction takes place by oogamy. i. (The male reproductive structure is called a (i) **globule** and the female one, a (ii) **nucule,** though they are sometimes loosely called antheridium and oogonium respectively. They are always produced at the nodes of the so-called leaves and occupy the sides facing the main axis. Most of the species are homothallic, though heterothallic species are not uncommon. The nucule and the globule have definite orientations with respect to each other, the former being placed above the latter, and they may develop either simultaneously or the globule develops earlier.)

ii) (A superficial nodal cell) of the so-called leaf facing towards the main axis (forms an apical cell that cuts off two cells, the upper one elongates and forms the internodal cell that acts as the **pedicel** of the future globule, and the lower cell divides and re-divides to form a node. The apical cell enlarges, becomes spherical and divides by two vertical planes to form four cells which re-divide transversely to form an octant. Each of these octants divides into two cells by wall parallel to the surface (periclinal division) forming two daughter cells, of which the outer one divides again in a similar manner so that a row of three cells is formed. Of these, the outer cell is a **shield cell,** the middle one is a **handle cell** or **manubrium,** and the innermost one is a **primary capitulum.** The shield cells, as they attain maturity, enlarge and expand

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laterally so that a cavity gradually develops within the globule. With the gradual development of the cavity, the handle cells or the manubria also elongate radially and there is an ingrowth of the pedicel cell within the cavity, the primary capitula remaining in close contact with one another. The outer wall of a mature

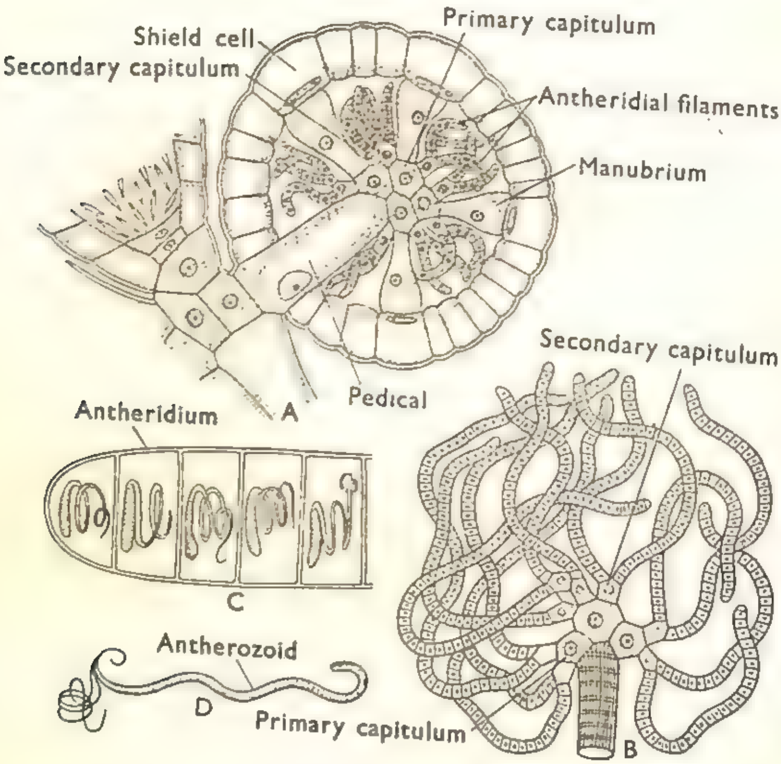


Fig. 78. *Chara.*
A, Section through a globule showing its different parts; B, The handle cell with antheridial filaments on secondary capitulum; C, A portion of antheridial filament; D, An antherozoid.

shield cell develops radial inward projections (anticlinal walls), thus incompletely dividing the cell into several compartments. Each primary capitulum divides and forms six **secondary capitula,** which may or may not divide any further. The secondary capitula cut off cells which form branched or unbranched filaments. These filaments may also be produced from the primary or tertiary

capitula. Each **antheridial filament** may contain about 5-150 cells, each of which when fully developed becomes an antheridium, whose protoplast is metamorphozed into a biflagellate, spirally coiled **antherozoid.** At maturity, the globule appears bright yellow or red in colour and the shield cells separate from one another, thus exposing the mature antheridial filaments which are attached to the capitula on the handle cells or manubria. The liberation of antherozoids in the surrounding water then takes place in the morning through a small pore on the antheridial wall.)

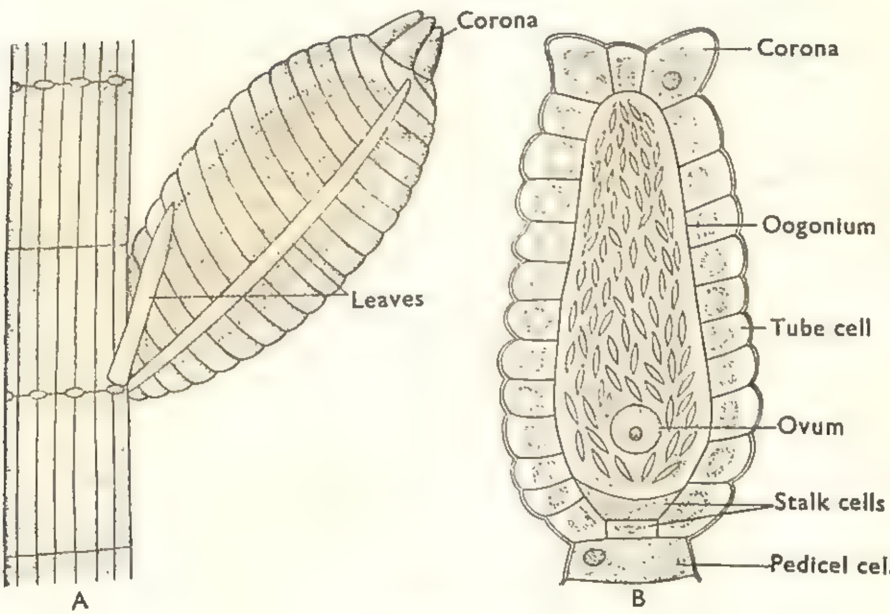


Fig. 79. *Chara.*
A, A mature nucule; B, Vertical section through the same.

Structure of Nucule -

(ii) (A cell of the basal node of the nucule, facing towards, the main axis, divides to form a row of three cells. The lowermost cell does not divide at all, but simply enlarges and becomes the **pedicel cell** supporting the developing nucule. The uppermost cell acts as the mother-cell of the oogonium. This cell elongates and divides unequally by a transverse wall into a short **basal cell** or **stalk cell** and an upper elongated **oogonium.** The protoplast of the oogonium is gradually metamorphozed into a uninucleate

oosphere or **ovum** or **egg,** which becomes densely filled with large starch grains prior to fertilization. During the development of the oogonial mother-cell the median cell of the original axial row divides and re-divides by vertical walls into five lateral cells surrounding a central one. These lateral cells then grow upwards forming a protective covering or sheath of the oogonial mother-cell. Each of these cells then divides transversely, so that two tiers of five cells each are formed. The cells of the lower tier, called the **tube cells,** elongate spirally several times surrounding the enlarging oogonium and bear the upper tier of five cells which mature into the **corona** at the top of the nucule. At maturity, the cells of the sheath slightly separate just below the corona forming five angular openings.)

Fertilization then follows in which the free-swimming antherozoids enter the nucule through the angular openings, one ultimately penetrates the oogonium through its gelatinized wall and finally unites with the ovum there. The fertilized ovum then secretes a thick wall and forms an oospore. As the oospore matures the inner tangential walls of the tube cells also thicken forming an additional protective covering round it, while the unthickened portions of the sheath become disorganized. This oospore, surrounded by the thickened sheath, falls to the bottom of the pool and germinates after a resting period of several weeks.

During germination, the zygote-nucleus travels towards the apex of the zygote and divides by reduction division into four haploid nuclei. This is followed by the division of the zygote into two asymmetrical cells, of which the distal one is uninucleate and the basal, trinucleate. The distal cell is then exposed by the rupture of the zygote wall and undergoes division into two cells by a vertical wall. Of these two cells, one becomes the **rhizoidal initial cell** and the other, **protonemal initial cell.** The nuclei of the basal cell eventually disintegrate. The rhizoidal initial cell forms a colourless rhizoid with nodes and internodes. From its nodes **secondary rhizoids** also develop. The protonemal initial cell also elongates and forms a green filamentous **primary protonema,** differentiated into nodes and internodes. The lowermost node of this primary protonema may bear **rhizoidal** or **secondary protonemal appendages.** The next upper node also bears a whorl of appendages, of which all but one are simple

green filaments. The remaining one elongates into a typical axis of the new *Chara* plant.

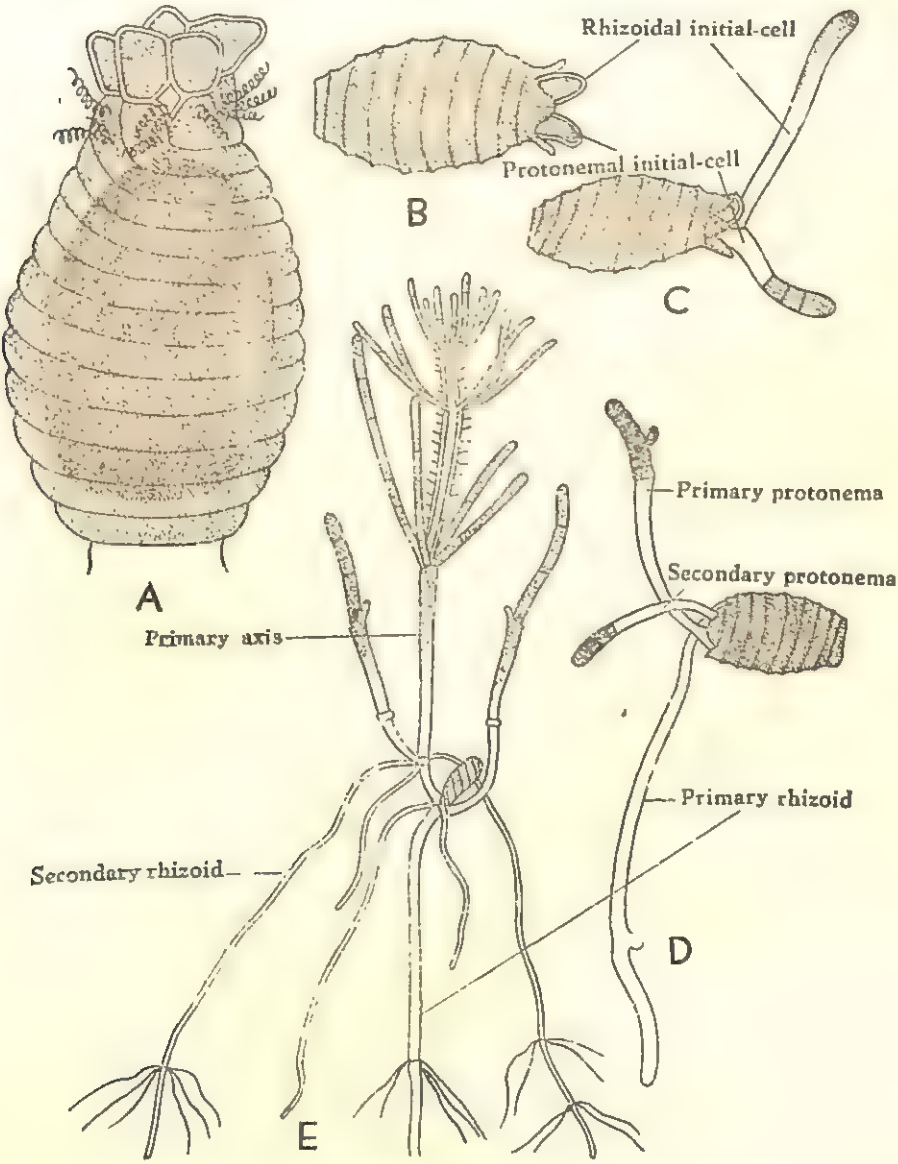


Fig. 80. *Chara.*
A, Entry of antherozoids through the angular slits just below the corona; B—E, Germinating zygotes and development of the young plant.

In the life history of *Chara*, the plant body represents only the

gametophytic generation, and the nucleus of the zygote represents the sporophytic stage in the entire life cycle.

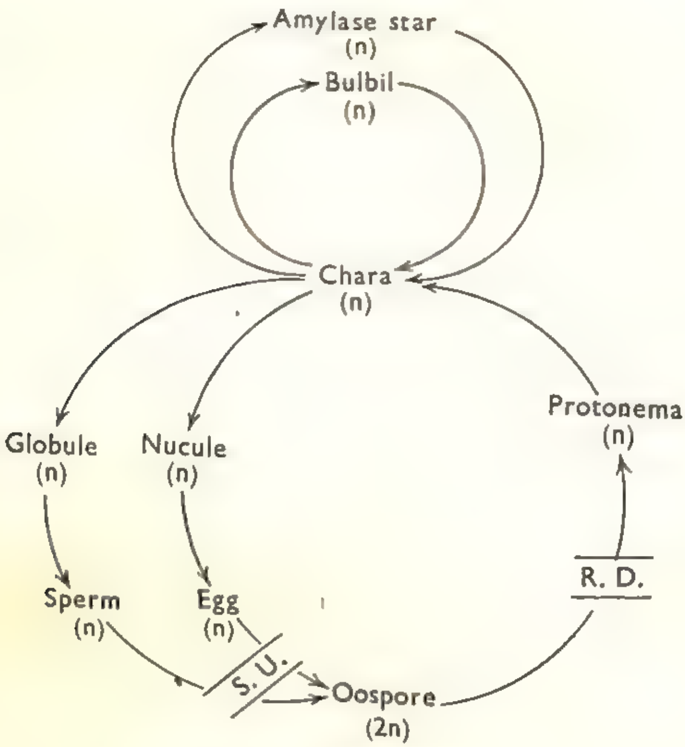


Fig. 81. Life cycle of *Chara*.

NITELLA

(Fam. Characeae)

Nitella is allied to *Chara* and is usually widely distributed in freshwater forming extensive sub-aquatic meadows, but growing deeper than *Chara*. Most species are often incrustated with abundant calcium carbonate and these eventually form considerable calcareous deposits at the bottom of water in which they live.

The common Indian species of *Nitella* are *N. mirabilis*, *N. acuminata*, *N. flagellifera*, *N. mucronata*, *N. hyalina*, etc.

Vegetative body

The plant body typically shows equisetoid habit with nodes and internodes and the usual whorled arrangement of lateral branches

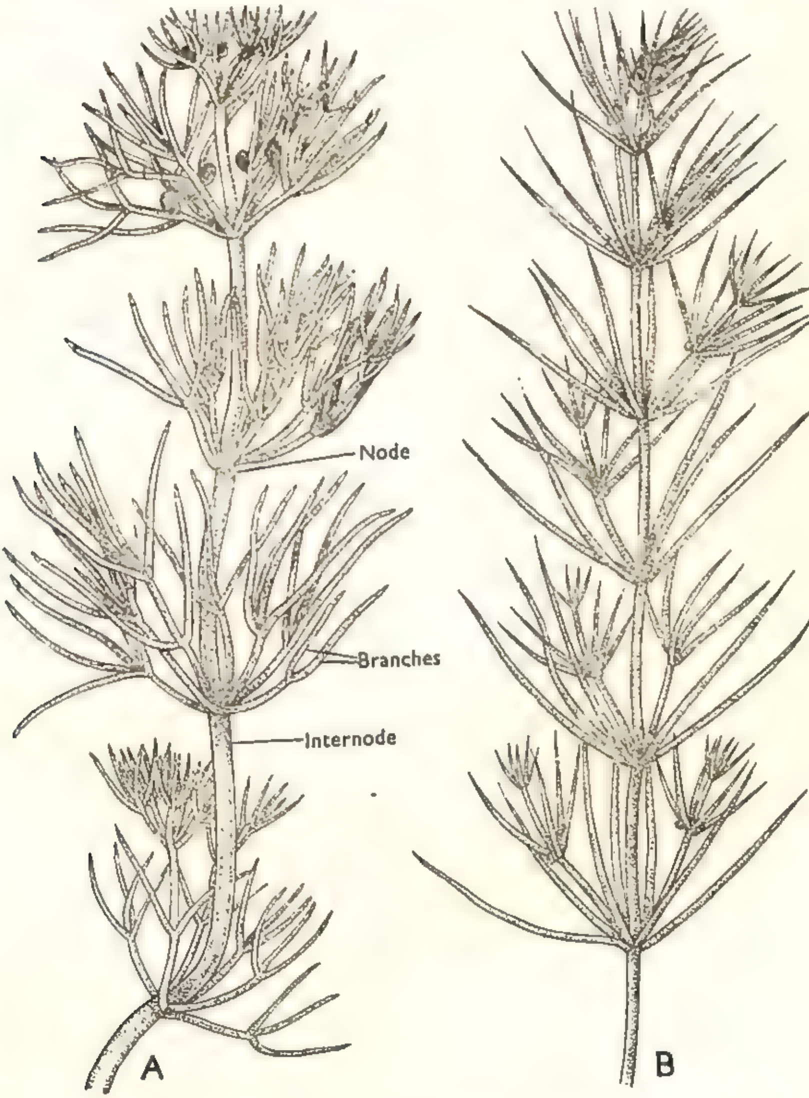


Fig. 82. *Nitella*.
A, Reproductive shoot; B, Vegetative shoot.

of limited growth, the so-called "leaves". It is anchored to the substratum by means of multicellular rhizoids. The rhizoids do not show differentiation into nodes and internodes, but possess oblique

septa. In addition to the function of anchoring, they also absorb mineral salts from the substratum. Each internode consists of a single elongated cell, often attaining a length of about 25 cm., and is never corticated like *Chara*. Usually, the branches of limited growth are produced singly from the oldest lateral branch, but in some cases a second branch may develop from the next oldest lateral one. The growth of the primary or secondary axis takes place by means of successive divisions of the dome-shaped apical cell. In some cases, the basal nodes of the short lateral branches produce unicellular spinous outgrowths, the so-called **stipules,** which may also be sometimes branched.

As in *Chara*, the cells contain numerous discoid and oval chloroplasts without any pyrenoid and a single nucleus, and these are embedded in the peripheral layer of cytoplasm surrounding a large central vacuole. The nucleus multiplies by the process of amitosis. Protoplasmic streaming is also noticeable. The cell wall mainly consists of cellulose. The superficial layer is of an unknown composition and is more or less gelatinous in texture in which deposition of calcium carbonate takes place.

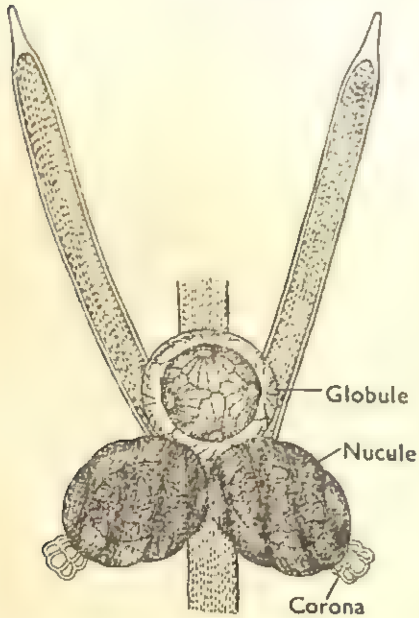


Fig. 83. *Nitella*. Sex organs.

Reproduction

Nitella reproduces by vegetative and sexual methods.

Vegetative reproduction occurs at all stages in the life cycle of *Nitella*. It takes place by the formation of secondary protonemata originating from the basal node of the primary rhizoid or the rhizoidal node of protonema. Secondary protonemata sometimes develop from the dormant apical portion of the surviving nodes of an older plant after a period of perennation. A fragment of the plant with a node, when placed under favourable conditions, may give rise to secondary protonemata.

Occasionally, tuber-like outgrowths develop from the rhizoids or portion of the axis embedded in the substratum.

The plant is either homothallic or heterothallic. Sexual reproduction takes place by oogamy. The essential features of reproduction are like those of *Chara* but with a few minor differences. As a general rule, the sex organs, **nucule** and **globule,** develop in close juxtaposition in homothallic species, but in several heterothallic ones they occur on different individuals. They are usually borne on secondary branches of limited growth and develop from the upper nodes of the primary laterals. They are generally so orientated that the nucule is directed downwards and the globule, upwards. Elongated one-celled branchlets, the so-called **brancteoles,** usually develop from basal node of the globule and constitute a loose envelope around the nucule. At maturity, the globule is spherical, bright yellow or red in colour, while the oval nucule with its spirally coiled, bright green threads appear very conspicuous to the naked eye. The mode of development of the sex organs, the process of fertilization and embryogeny are more or less similar to those of *Chara*. It is to be noted, however, that the corona is made up of two tires of cells.

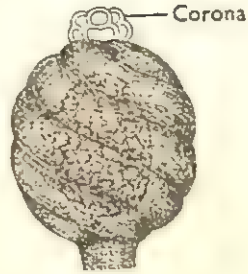


Fig. 84. *Nitella*. A mature nucule.

Systematic position and affinities of Charales

The Charales occupy rather an uncertain and ill-defined position in the plant kingdom. Though they are green in colour, they differ markedly from all other members of the Chlorophyceae by their vegetative body, sex organs and antherozoids. On account of these characters large number of algologists consider this group is quite separate from any other groups of algae, while some would even recommend its removal from the Thallophyta.

Strasburger placed the Charales in a separate Class. According to him the Characeae or Charophyta represent a group of highly specialized green-coloured thallophytes, whose origin might be traced back to the Chlorophyceae. But they cannot be directly connected with the other oogamous Chlorophyceae on account of the peculiar structure of their sex organs. On the other hand, they show some approach towards the Phaeophyceae in certain

characters, but differ from them mainly in having pure green-coloured chromatophores.

Sachs considered that the Charales are so very different from other groups of thallophytic organisms that they should form a special group by themselves coordinate in rank with Thallophyta Mussinae, which they resemble in the form of antherozoids but from which they differ also in the structures of their vegetative and reproductive organs. The distinctive characters of the nucule and the globule afford no indication or clue to any affinity of this group with other existing groups of plants.

Fritsch is of opinion that Charales should be regarded as an Order under the Chlorophyceae, becuase the tendencies characterizing them are found in other Orders of Chlorophyceae as well. Further, if it would have been possible to obtain detailed fossil records, probably all intermediate transitional forms to the complexities of the Charales could be noted. He also suggests that the complex vegetative body and reproductive organs are not restricted to the Charales alone as parallel cases of complexities can be found in other groups of algae also, as in the Ectocarpales of the Phaeophyceae.

In all probability, the Charales may be regarded as a remnant of many probable evolutionary lines of algae trying for colonization on the land. In course of such an attempt, they have advanced to some extent and some of their characters towards the higher land plants, while in others they still retain some of the characteristics of Chlorophyceae.

CLASS II. XANTHOPHYCEAE

Salient features

The members of this Class contain yellow-green chloroplasts owing to the preponderance of the yellow pigment, **xanthophyll.** Starch grains are never formed as product of photosynthesis and pyrenoids are mostly wanting. Oil is stored as a reserve food.

General characters

The most advanced members of this Class possess simple filamentous bodies, and they are distributed more widely in freshwater than in the sea. The cell wall is rich with pectic compounds, and is made up of two equal or unequal pieces, overlapping each other by their edges. There are usually several chloroplasts in each cell, and

they are discoid in form. Motile reproductive cells are generally provided anteriorly with two flagella (sometimes only one). Sexual reproduction is usually isogamous or may be rarely oogamous.

BOTRYDIUM

(Fam. BOTRYDIACEAE)

Botrydium is a terrestrial alga. It is usually found on damp soil, particularly on the drying muddy banks of streams, forming abundant granular patches covering the substratum.

The common Indian species of *Botrydium* are *B. divisum*, *B. granulatum*, *B. tuberosum*, etc.

Vegetative body

The thallus is unicellular and is differentiated into an upper subaerial part and a branched rhizoidal part, which penetrates the soil. The subaerial part is globose, pear-shaped or elongated, cylindrical in form, depending on the environmental conditions, and about 1-2 mm. in diameter. It is surrounded by a tough wall, within which is a peripheral layer of protoplasm surrounding a central vacuole. The protoplasm contains many nuclei and discoid chromatophores with pyrenoid-like bodies, but oil instead of starch is formed as food-reserve. The rhizoidal portion shows various degrees of branching and is colourless due to the absence of chloroplasts. Numerous nuclei are found distributed in the vacuolated cytoplasm. It is evident that within the body of the unicellular alga the protoplasm is continuous throughout, and is characteristic of a coenocyte.

Reproduction

Botrydium usually reproduces asexually, but sexual reproduction has also been reported in some cases. It is incapable of any vegetative reproduction.

Asexual reproduction takes place by means of zoospores, aplanospores or hypnospores.

When the plants are flooded with water, **zoospores** are produced. The protoplasm of the vescicular portion of the plant body, by repeated divisions, forms numerous uninucleate masses which

are ultimately metamorphozed into pear-shaped zoospores. Each zoospore possesses anteriorly two flagella of unequal lengths. Due to the gelatinization of the apical portion of the vesicle an opening

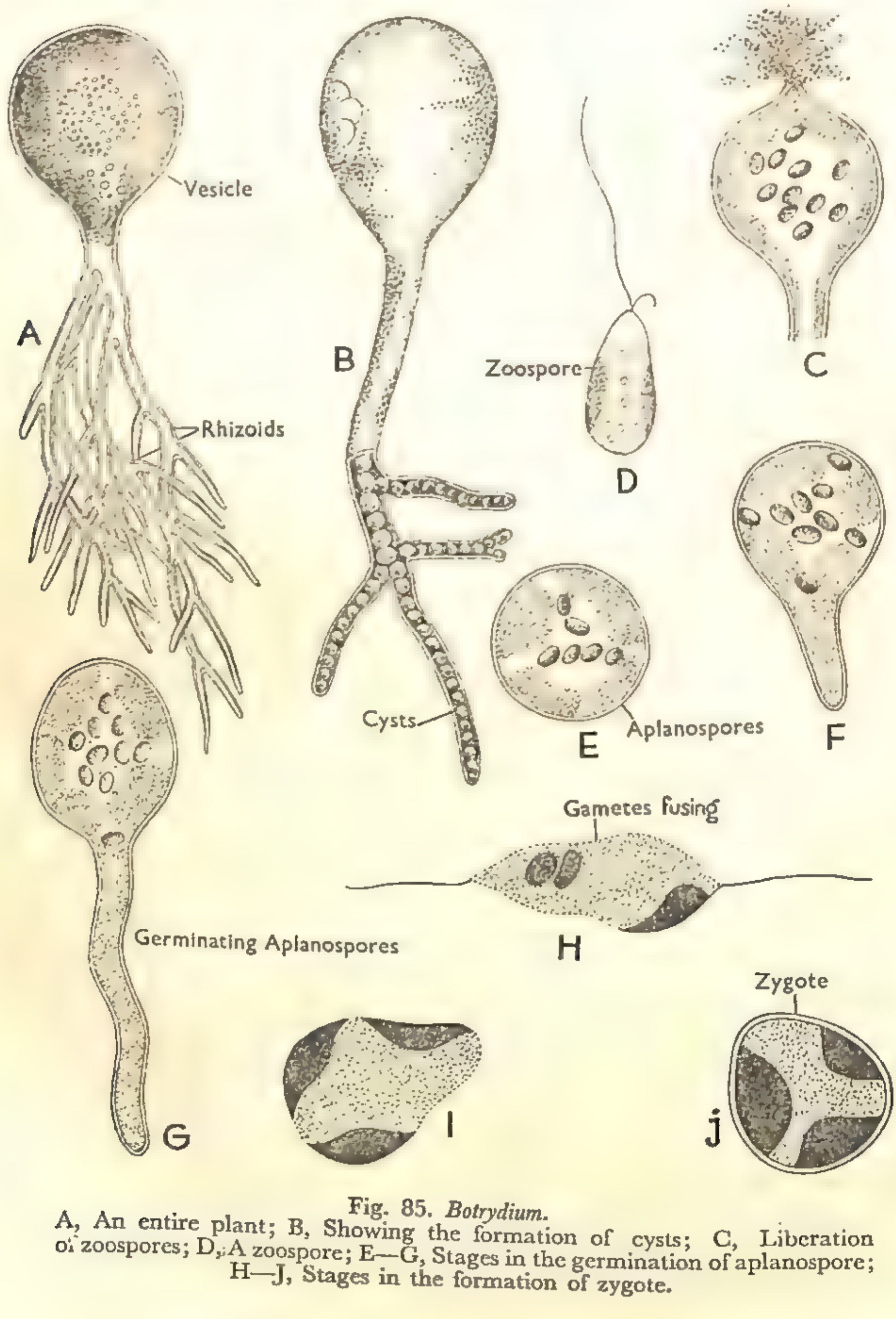


Fig. 85. *Botrydium.*
A, An entire plant; B, Showing the formation of cysts; C, Liberation of zoospores; D, A zoospore; E—G, Stages in the germination of aplanospore; H—J, Stages in the formation of zygote.

is formed, through which the zoospores escape and these finally develop into new plants.

When the plants grow in a comparatively dry soil, they form **aplanospores.** The formation of aplanospores is similar to that of zoospores, but the ultimate protoplasmic masses are either uninucleate or multinucleate, which become rounded and develop a wall around each. Aplanospores, under favourable conditions, germinate directly into new plants.

Thick-walled uninucleate or multinucleate **hypnospores** may also be formed from the aplanospores of the vescicular portion. In some cases, the protoplasm migrates into the rhizoidal portion and becomes separated into a number of multinucleate, serially-arranged segments, each of which eventually becomes surrounded by a thick wall. Uninucleate hypnospore germinates and directly forms a new thallus. Multinucleate hypnospores, on the other hand, at the time of germination forms a number of zoospores or aplanospores, each of which after liberation forms a new plant.

Sexual reproduction by isogamy has recently been reported. *Botrydium* is homothallic. Gamete-formation takes place within the vescicle, like zoospore-formation. The gametes, usually after liberation, fuse in pairs and form a zygote. The zygote germinates immediately. In some cases, parthenospores may also develop from the gametes.

CLASS IV. BACILLARIOPHYCEAE (DIATOMS)

Salient features

The members of this Class are either unicellular or form colonies. All are characterized by the presence of golden-brown chromatophores which, besides the usual pigments, contain some brown pigments of obscure nature. The cell wall is made up of both pectic substances and silica, and usually consists of two halves with rich ornamentations on their surface. The cells are either radially or bilaterally symmetrical. The members of Pennales show special type of sexual union between protoplasts of vegetative cells. They are probably all diploid. Diatoms are widely distributed both in fresh and salt water of all kinds. Some are also terrestrial.

General characters

The Bacillariophyceae, popularly known as diatoms, constitute a very large assemblage of unicellular algae. Owing to the colour of their chromatophores they appear to be brown algae, but they are usually considered as a separate and distinct group. They

are readily distinguished from other algae by the following salient features : (*a*) the plant is usually unicellular and always non-flagellate, the silicified wall consisting of two overlapping halves; (*b*) the photosynthetic reserve materials are fats and volutin but never starch; (*c*) the photosynthetic pigments of the chromatophores are masked by the presence of a golden-brown pigment known as **diatomin;** (*d*) special type of large rejuvenescent cells (**auxospores**) are formed, either directly from the vegetative protoplast or as a result of sexual union, a feature not found in other groups of algae.

Occurrence and distribution

Diatoms are inhabitants of both fresh and salt water, being usually associated together in great abundance. Some diatoms are either strictly marine or strictly freshwater. Both freshwater and marine diatoms may be sessile in habit or free-floating (plankton); when sessile, they are attached to other types of algae or affixed to rocks or other solid inanimate objects under water.

After the death of individual cells, the silicified wall of a diatom remains unaltered and great numbers of these walls are deposited at the bottom of ponds, lakes or any other body of water in which diatoms thrive. If the conditions are favourable, deposition goes on unimpeded for ages, and as a result, accumulation may attain a considerable thickness. Deposits of such fossil diatoms are known as the **diatomaceous earth,** which are found distributed all over the world.

Vegetative body

Diatoms are usually unicellular and display a great diversity of forms, but sometimes cells are united together to form simple filamentous or branched colonies. Each cell of a living diatom or its wall alone is called a **frustule,** which consists of two overlapping halves or **valves** that fit together like a pair of Petri dishes. The outer valve is called **epitheca** and the inner, **hypotheca.** Each frustule thus presents two different views, namely **girdle view** and **valve view,** according to the position in which it is observed.

Both the valves of a frustule have their outer walls strongly silcified and made up of an organic matrix chiefly consisting of pectin, there being no microchemical reaction for cellulose. The siliceous deposit on a valve is not uniform but in the form of numerous fine transverse markings or ribs and also as small protuberances

and **areolae.** The areolae may consist of minute vertical pores as incomplete canals which do not perforate the wall completely.

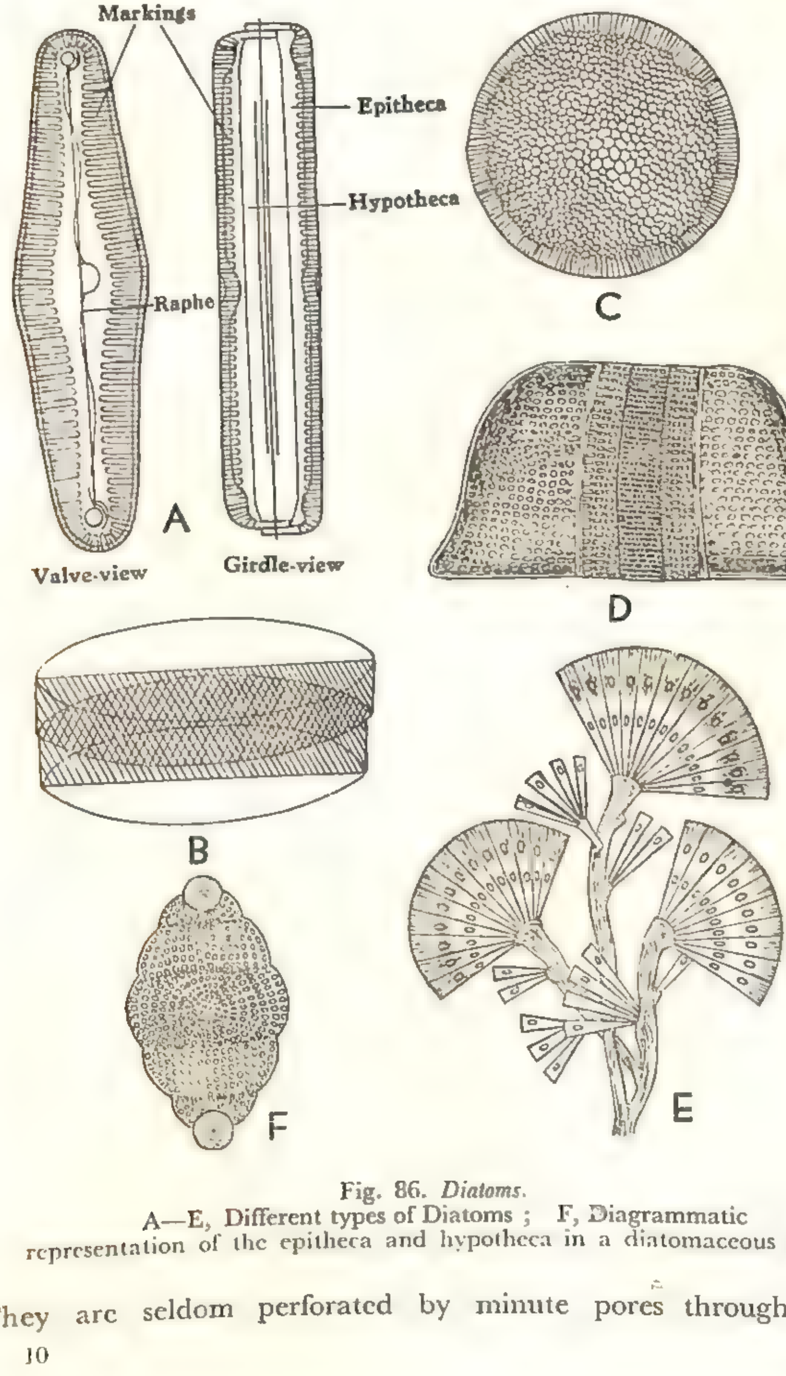


Fig. 86. *Diatoms.*
A—E, Different types of Diatoms ; F, Diagrammatic representation of the epitheca and hypotheca in a diatomaceous cell.

They are seldom perforated by minute pores through which

mucilagenous secretion comes out. The ornamentation is either radially symmetrical with reference to a central point (**Centric diatoms**), or bilaterally symmetrical or asymmetrical with respect to a long axis (**Pennate diatoms**).

Lying internal to the cell wall there is a thick layer of cytoplasm as a primordial utricle surrounding a conspicuous central vacuole and containing one or more chromatophores, with or without one to several pyrenoids. There is only one spherical to ovoid nucleus of the normal type embedded in the peripheral layer of cytoplasm, or it is suspended in a mass of cytoplasm at the centre of the vacuole and is connected to the peripheral layer by means of broad cytoplasmic strands.

The chromatophores are mostly rich golden brown in colour and vary in shape and number from species to species. This particular colour of the chromatophores is due to the presence of a special pigment, known as **diatomin,** which masks the photosynthetic pigments, chlorophyll and the associated carotenoids. Food reserves are in the form of fatty oil accumulated as droplets of variable size in the cytoplasm or in the chromatophores.

Many planktonic unicellular diatoms exhibit spontaneous movements, either as a series of jerks directed along the long axis of the cell or as forward and backward progression and retrogression, and these are also seen in some of the colonial forms.

The common Indian species of Centric diatoms are *Melosira varians*, *M. jurgensii*, *Coscinopiscus radiatus*, etc., while those of Pennate ones are *Synedra ulna*, *S. acus*, *Navicula stauroptera*, *N. viridis*, *Gomphonema acuminatum*, *Rhopalodia gibba*, *Asterionella formosa*, etc.

Reproduction

Diatoms reproduce vegetatively by cell division. During the process the protoplast of the mother cell first increases in bulk, and, as a result of this increase, the two valves of the frustule are slightly pushed apart. This is first followed by nuclear division and subsequently by longitudinal cleavage of the cytoplasm in such a manner as to form two daughter protoplasts, each being retained within a valve. Each daughter protoplast forms a new cell wall on its naked side just fitting into the old valve. Thus, the two valves of the frustule are of different ages. The daughter cells after their formation usually separate but may remain attached in some species. Of the two daughter cells, thus formed, one is obviously larger than

the other, and if this process be repeated the daughter cells become gradually smaller and smaller until it reaches a definite minimum size, when no further cell division occurs. The plant then takes recourse to another method of reproduction by which the size of the original plant is restored. This transformation in size from a small cell to a larger one is due to the formation of a special rejuvenescent cell, called the **auxospore.**

Among Centric diatoms auxospores are formed singly within vegetative cells. During the process, the two halves of a frustule are pushed apart, the exposed protoplast swells thrice its original size, becomes rounded, and is finally enclosed by two new silicified halves secreted for the purpose. The auxospores, thus formed, remain

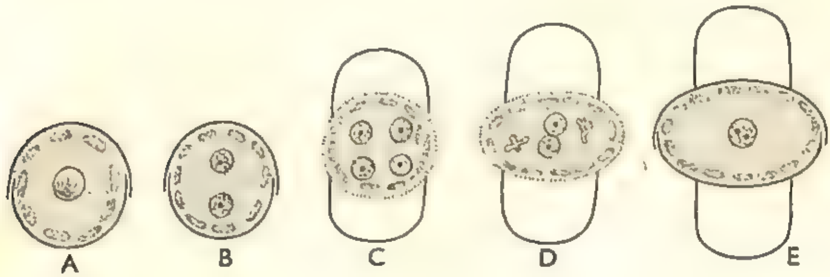


Fig. 87. *Diatom.*
Diagrammatic representation of stages in the formation of an auxospore in a centric diatom.

attached to the walls of the parent cell for some time and subsequently, each germinates by transverse division of its protoplast forming two cells, which usually divide and re-divide in the same plane. The cells, thus formed, are larger than the original vegetative cell.

Frequently in marine planktonic species of Centric diatoms, the protoplast of a vegetative cell contracts and recedes away from the wall. Following this, a new cell wall consisting of the two usual overlapping halves is secreted around the contracted mass of protoplasm, thus forming a thick-walled **statospore,** also known as **endospore** or **cyst.**

Besides the asexual modes of formation of auxospores as discussed above, they may also be formed sexually. In a large number of cases, "microspores" (4 to 128 in number) are formed within a cell by meiotic divisions. These are considered to be flagellate and are

interpreted both as **isogametes** as well as **motile male gametes.** In the latter case they come out of the parenet cell, swim towards mother cell containing a protoplast with a single haploid nucleus (regarded as an egg), and there fuses with it. Thus a zygote is formed, which subsequently develops into an auxospore.

In one genus of the Centric diatoms, the nucleus in a frustule has been found to divide meiotically giving rise to four haploid nuclei. Of these, two degenerate, while the other two unite forming a diploid zygote nucleus. The zygote then enlarges considerably and develops into an **auxospore.**

Among Pennate diatoms auxospores are formed in several ways as follows.

In some cases two cells become enveloped by a gelatinous sheath, within which they lie either side by side or end to end.

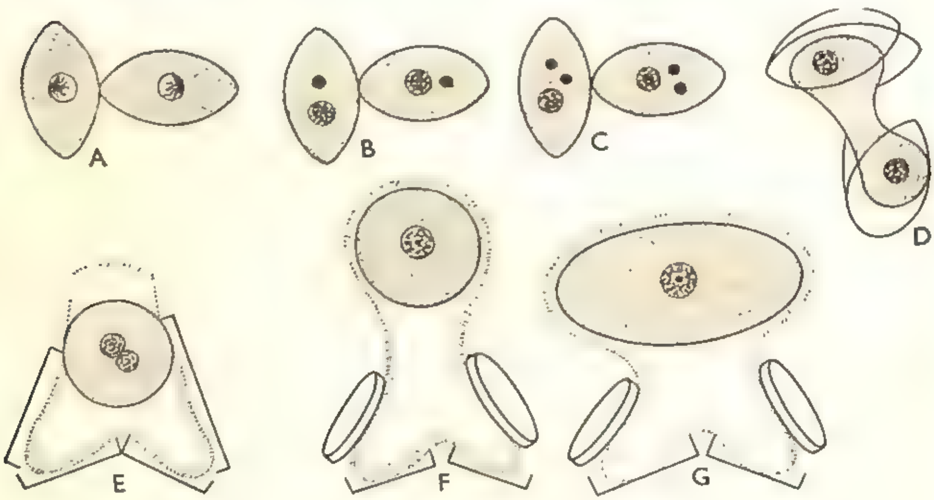


Fig. 88. *Diatom.*
Diagrammatic representation of stages in the formation of an auxospore by the conjugating cells of a pennate diatom.

The diploid nucleus in each of these cells undergoes meiosis. In some species, after the completion of the meiotic division, only one haploid nucleus in each cell persists and enlarges, while the other three degenerate. In other cases, however, of the two daughter nuclei produced in a cell after the first meiotic division, one undergoes degeneration immediately ; the surviving nucleus divides for the second time, and again there is degeneration of one of these

two newly formed nuclei. In either case, the two masses of protoplast, each with a haploid nucleus, unite sexually giving rise to a binucleate zygote. The zygote nuclei subsequently fuse together to form a diploid nucleus. The zygote itself then becomes enlarged and is known as an **auxospore.**

Certain genera of Pennate diatoms form two auxospores by the conjugation of two cells. As in the previous cases, two cells come side by side and become enclosed by a common sheath. The

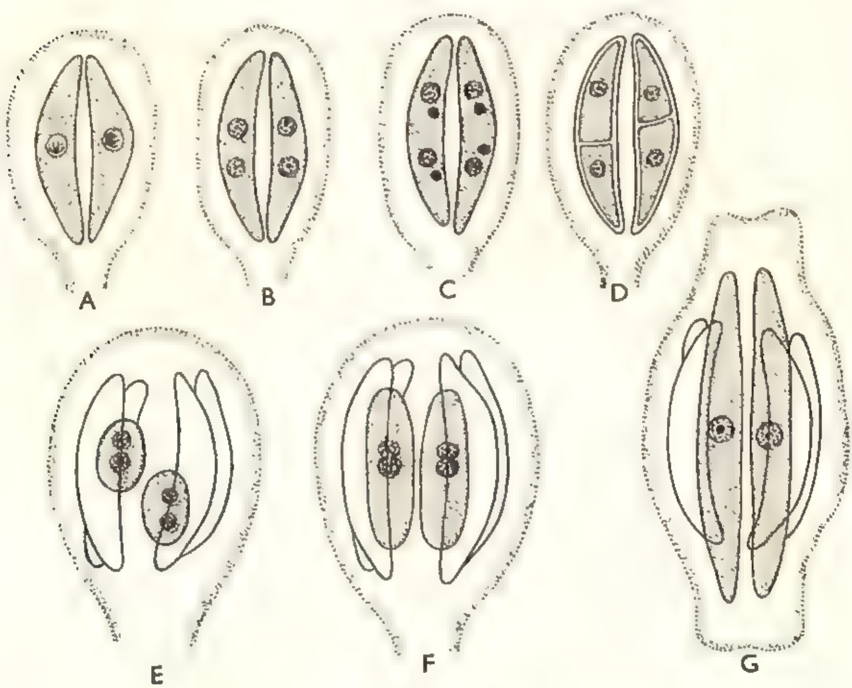


Fig. 89. *Diatom.*
Diagrammatic representation of stages in the formation of two auxospores by two conjugating cells of a pennate diatom.

nucleus in each cell divides meiotically and gives rise to four haploid nuclei, of which two degenerate, either before or after cytokinesis. In the latter case, the nuclear divisions are, however, presumed to be meiotic. Subsequently, in each cell, two gametes are produced, which may be equal or unequal in size. Usually, the two gametes, thus formed, in a cell are amoeboid, which unite with similar gametes of adjacent cell, somewhere midway in between

the original cojugating cells. When the gametes are, however, unequal in size, the smaller one in a cell is amoeboid and lies opposite to the immobile larger one situated in the other cell. As a result of fusion of gametes two zygotes are formed, which become considerably enlarged forming two **auxospores.**

In still others, a single frustule forms a solitary **auxospore.** In one genus, the nucleus of a cell divides meiotically forming four haploid nuclei. Of these two nuclei degenerate partially, and then the protoplast undergoes a division giving rise to two gametes, each of which possesses one normal nucleus and a degenerate one. These gametes unite together and a zygote is produced, which enlarges usually into an **auxospore.** In another doubtful case, however, two of the four haploid nuclei produced undergo degenration as usual. But cytokinesis fails to take place. The two sister

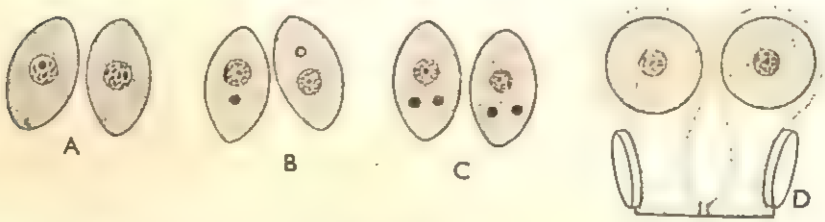


Fig. 90. *Diatom.*
Diagrammatic representation of stages in the parthenogenetic formation of two auxospores by two conjugating cells of a pennate diatom.

nuclei simply fuse together forming the diploid nucleus of the auxospore. In some rare cases, two cells may come in contact as in normal types. But no conjugation takes place and ultimately they give rise to a pair of auxospores parthenogenetically.

An auxospore, no matter how it is formed, divides longitudinally to form two vegetative cells.

Economic importance

The uses of the diatomaceous earth are very varied, *viz.*, as a filtering material, as a substance used in insulation of boilers, blast furnaces, etc., as a cementing material, as a mild abrasive in metal polishes and toothpastes, as an absorbent for liquid nitroglycerine (the explosive material of the dynamite), and as a material for painting the ship to protect it against the attack of sea-barnacles.

CLASS IX. PHAEOPHYCEAE

Salient features

The Phaeophyceae, or the brown algae, represents a group of marine algae having wide range of distribution and includes forms varying from plants of microscopic size and simple structure to the largest and most highly differentiated bodies of macroscopic forms among the thallophytes. Its members are characterized in having : (1) cells with definite nuclei and plastids with all the photosynthetic pigments, chlorophyll *a*, chlorophyll *b*, carotene and xanthophyll and an accessory golden brown pigment, called **fucoxanthin,** which usually masks entirely the green colour of the chlorophyll ; (2) thalli which are always multicellular and in most cases possessing a definite macroscopic form ; and (3) flagellate reproductive cells, zoospores or gametes, which are pyriform in shape with two laterally inserted flagella of unequal lengths. The two latter characters separate this group from both the green and red algae.

General characters

With the exception of two or three freshwater species, nearly all the brown algae are marine, and these forms attain their greatest development in the cool ocean waters of the temperate and frigid (arctic and antarctic) zones than those which are inhabitants of warm tropical seas. Most of the marine species grow attached to rocks or similar other objects along the shores upto a depth of about 17 metres under the water. Some of the giant 'kelps' (*e.g.*, *Laminaria* and others) grow along the Pacific coasts of America on rocks at a depth, even beyond 20 metres, below the surface of water. Others may grow as epiphytes in association with other algae or within their tissues as endophytes.

The Phaeophyceae show great diversity in form and structure of the plant body among its various members and in a great majority of cases possessing regular alternation of generations between free-living multicellular gametophytes and sporophytes. Both the generations may be identical in form and structure, or the sporophyte is larger than the gametophyte, or *vice versa*. Both these generations may be annual or perennial, or the gametophyte is annual and the sporophyte, perennial. The range of thalli varies from genus to genus, all the way beginning from single, few-celled gametophytes or sporophytes of microscopic size to definite macroscopic forms attaining a length of 27-33 metres or more, without having any relationship between the size and longevity of the plants concerned. The gametophyte or the sporophyte of a plant, possessing a definite form, is differentiated into a holdfast supporting an upright simple or branched portion, which is either solid or hollow and tubular, but may also be spherical or compressed. Great complexity

in form is encountered among the 'kelps', where the thallus is differentiated into a **root-like holdfast,** a simple or branched stem (**stipe**) and one or more **leaf-like blades.**

The cell of brown algae has a distinct cell wall, which is differentiated into an inner firm cellulose portion and an outer gelatinous portion made up of a pectic compound, known as '**algin.**' The protoplast is vacuolated and generally contains a single nucleus of normal form and structure. The division of protoplast takes place by mitosis. During the division, centrosomes become evident near the poles, and these appear to be a constant feature in the dividing cells of the various members of the Phaeophyceae. There is usually more than one plastids in each cell and they are always without pyrenoids. They are usually flattened or discoid in shape and may have irregular outlines. The plastids, in addition to the four photosynthetic pigments, contain a golden brown carotinoid pigment, **fuco-xanthin,** which is supposed to be a mixture of two pigments, **fuco-xanthin a** and **fuco-xanthin b.** Food reserves are in the form of carbohydrates which are found in a dissolved state in the vacuoles and in the cytoplasm. Of these, sugar is present in small quantity. A dextrin-like carbohydrate (polysaccharide) known as '**laminarin**' is always present. Another widely distributed carbohydrate is **mannitol.** Fats and oils are also found in some species.

Reproduction

The methods of reproduction in Phaeophyceae are very diverse and a brief summary of the principal methods has been given below.

Many brown algae reproduce by vegetative method by the process of fragmentation of the young or adult thallus. Fragments of the thallus, thus produced, may become detached from the parent plant and float away to form new individuals, or they remain united with one another forming an aggregation of individuals, being attached to the substratum by the common holdfast. In some cases, special reproductive branches (**propagula**) are formed and these are separated from the parent plant, ultimately developing into new individuals.

All brown algae, excepting the *Fucus* and a few allied genera, reproduce asexually by the production of zoospores or aplanospores. The zoospores are produced within both **unilocular**

(or unicellular) and **plurilocular** (or multicellular) **sporangia** and are *always borne on the diploid thallus* (sporophyte). The unilocular sporangium is a true sporangium, because reduction division of the uninucleate protoplast takes place prior to the formation of the haploid zoospores. The nucleus of the protoplast first divides reductionally into two nuclei, which subsequently divide and re-divide mitotically into 32, 64 or 128 nuclei. This is followed by the cleavage of the protoplast forming uninucleate masses, each of which is finally metamorphozed into a biflagellate zoospore. Each of these zoospores, after liberation, produces a haploid thallus (gametophyte). On the other hand, the zoospores produced by the plurilocular sporangium are diploid, each of which on germination gives rise to a diploid thallus, similar to the thallus from which it is derived. These zoospores are, therefore, termed **neutral zoospores** and the sporangium, **neutral sporangium.** During the formation of neutral zoospores, the uninucleate protoplast of each cell of the plurilocular sporangium (neutral sporangium), without undergoing reduction division, is directly metamorphozed into a neutral zoospore with two flagella. Thus, by the neutral zoospores the same generation is reduplicated. Sometimes the unilocular sporangium, instead of producing the zoospores, may produce 4-8 large, non-flagellate aplanospores.

Sexual reproduction in the brown algae may be a case of (i) isogamy, *i.e.*, by the union of two motile morphologically identical gametes, (ii) anisogamy, *i.e.*, by the union of two motile gametes of unequal size, and (iii) oogamy, *i.e.*, by the union of a motile, flagellate antherozoid with a non-motile, non-flagellate, passive egg. The iso- and aniso-gametes are produced within multicellular gametangia, which are similar in appearance with the neutral sporangia but these are *always produced on the gametophyte*, which is either homothallic or heterothallic. The zygotes, thus produced, develop into new sporophytes. Several members of the Phaeophyceae are oogamous and heterothallic. The male sex organ, the antheridium, may be unicellular or multicellular, and the entire protoplast of each cell is directly metamorphozed into a single antherozoid with two flagella. The female sex organ, the oogonium, is always unicellular containing within it 1-8 oospheres or eggs. In some cases, the egg is extruded from the oogonium or even discharged from it, so that fertilization takes place outside the body of the oogonium.

When sexual union fails, the gametes either degenerate or the unsuccessful gametes may develop into parthenospores.

Alternation of generations

Previously it was thought that the Phaeophyceae do not possess any alternation of generations. But, it is well known at present that all the members of this Class, excepting the Order Fucales, have a typical alternation of generations, which may be isomorphic (*e. g.*, Ectocarpales, Dictyotales, etc.) or heteromorphic (*e. g.*, Laminariales, Desmarestiales, etc.). These alternations have been studied chiefly under laboratory conditions, and for this purpose cultures should be examined starting both from the zoospores as well as the zygotes.

The Laminariales and the Dictyotales have a gametophyte regularly alternating with a sporophyte and *vice versa;* furthermore, this alternation is obligatory. On the other hand, there is a large number of brown algae where the alternation of the two generations is not only well marked, but also further complicated by a reduplicating of the sporophytic generation, as in the case of Ectocarpales. This reduplication of the sporophyte generally takes place by the formation of neutral spores within neutral sporangia followed by a reduction or even complete suppression of the unilocular sporangia.

In many of the brown algae, during the winter season, the neutral spores produce gametophyte-like filamentous dwarf plant known as the **plethysmothallic.** A plethysmothallus usually bears neutral sporangia and occasionally unilocular sporangia. When the former are produced plethysmothallic plants are frequenthy formed in succession.

A reduplication of the gametophytic generation in certain members has also been noted, but it is not a very frequent phenomenon.

The Fucales, however, present a very naughty problem, because here a many-celled diploid generation alternates with a one-celled haploid stage. Strasburger regards the *Fucus* plant itself as a sporophyte and antheridia and oogonia as micro- and mega-sporangia respectively, the gametophytic stages being restricted to the sperms and eggs only. Yamanouchi and Lloyd Williams also hold the same view. Church, however, challenges this idea seriously and considers that *Fucus* is a gametophyte and is a very much advanced plant, which may be compared to an animal, becuase there is no

other method of reproduction in the entire life history cycle, excepting that taking place by means of sperms and eggs only.

Classification

The Phaeophyceae has been divided (Fritsch, 1935) into the following *nine* Orders :

Order 1. Ectocarpales. Plants filamentous, pseudo-parenchymatous or truly parenchymatous in form; asexual reproduction by zoospores produced from unilocular and plurilocular zoosporangia; sexual reproduction is usually oogamous, rarely anisogamous. Examples—*Ectocarpus, Punctaria, Castagnea,* etc.

***Order 2. Tilopteridales.** Plants filamentous; asexual reproduction by monospores or by zoospores produced from unilocular sporangia; sexual reproduction perhaps anisogamous. Examples—*Tilopteris, Haplospora,* etc.

***Order 3. Cutleriales.** Plant body generally composed of thread-like structures; asexual reproduction by zoospores produced in unilocular sporangia; sexual reproduction anisogamous. Examples—*Cutleria, Zonardinia,* etc.

***Order 4. Sporochnales.** Thallus bulky and complex; asexual reproduction by zoospores formed within unilocular sporangia; sexual reproduction possibly oogamous. Examples—*Sporochnus, Carpomitra,* etc.

***Order 5. Desmarestiales.** Thallus uniaxial in construction with complex cortication; asexual reproduction by zoospores formed within unilocular sporangia; sexual reproduction oogamous. Examples—*Desmarestia, Arthrocladia,* etc.

Order 6. Laminariales. Plant bulky, body truly parenchymatous; asexual reproduction by zoospores formed within unilocular sporangia; sexual reproduction distinctly oogamous. Examples—*Laminaria, Macrocystis, Postelsia,* etc.

***Order 7. Sphacelariales.** Plant small, parenchymatous, heterotrichous; asexual reproduction by zoospores formed within unilocular sporangia; sexual reproduction isogamous. Examples—*Sphacelaria, Halopteris,* etc.

Order 8. Dictyotales. Plants with frequent dichotomous branching and slightly differentiated parenchymatous forms; asexual reproduction by non-motile tetraspores formed within

*Not treated in this book.

unilocular sporangia; sexual reproduction oogamous. Examples—*Dictyota*, *Padina*, etc.

Order 9. Fucales. Plants with parenchymatous forms and complex external and internal differentiations; asexual reproduction unknown; sexual reproduction oogamous. Examples—*Fucus*, *Sargassum*, etc.

ORDER 1. ECTOCARPALES

Plants filamentous, pseudo-parenchymatous or truly parenchymatous in form ; asexual reproduction by zoospores produced from unilocular and plurilocular zoosporangia ; sexual reproduction is usually oogamous, rarely anisogamous.

ECTOCARPUS

(Fam. ECTOCARPACEAE)

Ectocarpus is a brown alga, all species of which are marine and widely distributed. It has a life cycle in which there is an alternation of a free-living multicellular sporophytic generation with a free-living multicellular gametophytic generation, which are identical in vegetative structure.

Vegetative body

The thallus is differentiated into a prostrate, irregularly and more or less profusely-branched portion by means of which it remains attached to the substratum, and an erect portion made up of tufts of branched filaments, whose cells are joined end to end in a single series and are generally narrowed towards the apices of the branches. In some species, the older portions of the main branches are corticated by the development of a sheath formed by the descending rhizoidal branches. The protoplast of each cell is uninucleate and contains either many disc-shaped chloroplasts or a few band-shaped ones with irregular margins.

Reproduction

Ectocarpus reproduces both asexually and sexually.

The asexual reproduction takes place by the formation of biflagellate zoospores produced within unilocular or multilocular

zoosporangium borne by the sporophytic plant, usually terminally and singly on lateral branchlets.

The terminal cell of a branchlet enlarges considerably, becomes more or less ellipsoidal in shape and forms a unilocular sporangium. As it increases in size, the number of chloroplasts also increases considerably. The nucleus first divides by reduction division and is subsequently followed by several mitoses into 32-64 daughter

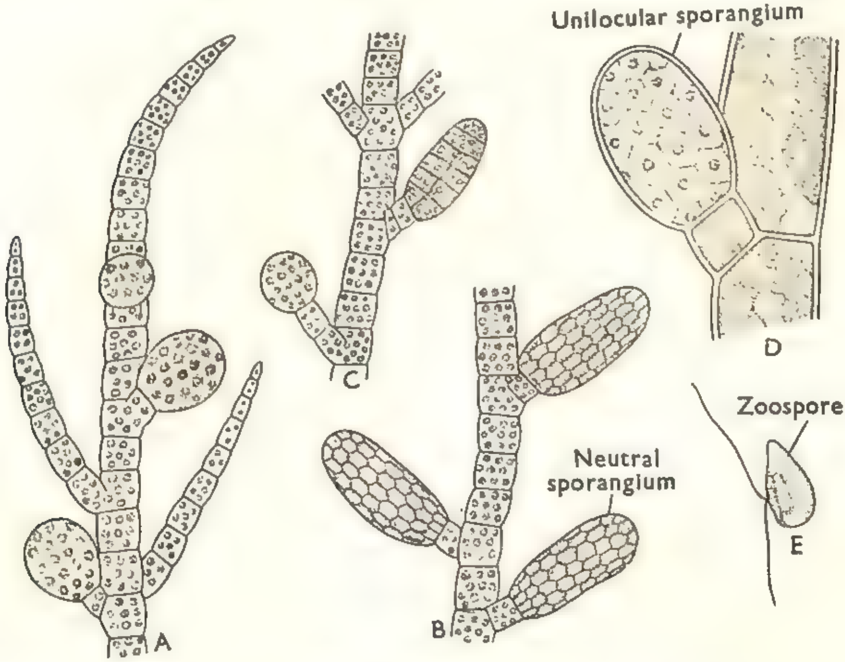


Fig. 91. *Ectocarpus*.
A, A portion of the thallus with unilocular sporangia; B, The same with neutral sporangia; C, The same with both unilocular and neutral sporangia; D, An unilocular sporangium showing division of its protoplasts; E, A zoospore.

nuclei. Then, there follows a progressive cleavage of the entire protoplast forming several uninucleate daughter protoplasts, each with a single chloroplast. Each daughter protoplast is finally metamorphozed into a zoospore with two laterally inserted flagella of unequal lengths. The whole mass of zoospores, thus formed, is extruded through a small opening at the apex of the zoosporangium, and they begin to swim freely in water in all directions. Each

zoospore, after a period of activity, comes to rest and develops into a new gametophytic plant.

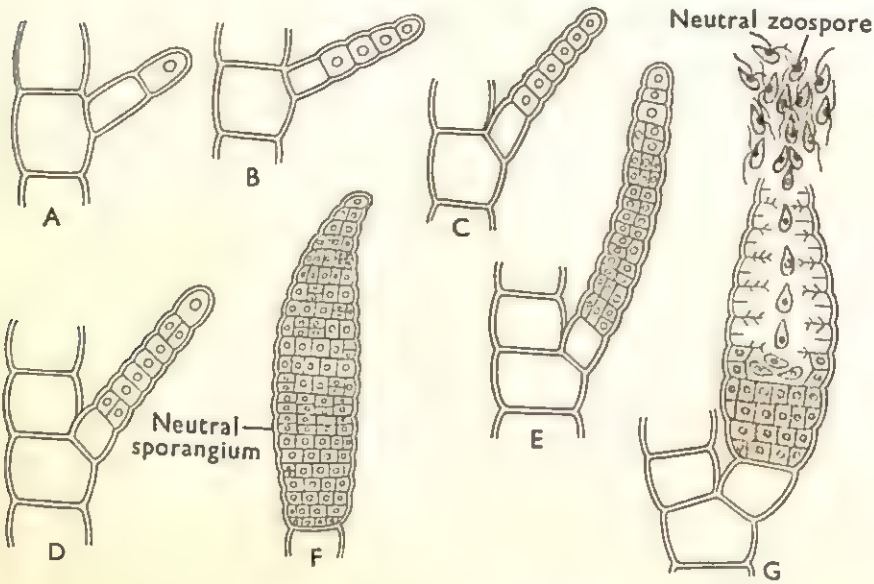


Fig. 92. *Ectocarpus.*
A—F, Successive stages in the development of neutral sporangia; G, Liberation of neutral zoospores.

The development of a multicellular sporangium also takes place from the terminal cell of a lateral branchlet. This cell, by repeated transverse and vertical divisions, forms hundreds of small cubical cells, arranged in 20-40 transverse tiers. The protoplast of each cell is then metamorphozed directly into a single biflagellate zoospore. These zoospores are liberated through a small pore, either terminal or lateral, on the wall. Each zoospore, after a period of activity, comes to rest and gives rise to a sporophytic plant, *i.e.*, a plant of the same generation from which it has developed.

It is to be noted that the unilocular sporangia are sporangial in nature in which reduction division takes place prior to the formation of haploid zoospores, and these are borne on the sporophytic plant (diploid). The multilocular sporangia borne by the sporophyte are also diploid. The zoospores produced by these structures are diploid, since there is no reduction division preceding their formation. In order to differentiate the multilocular sporangia from the multilocular gametangia, which are morphologically alike

but are borne on the gametophytic plant, these have been designated as **neutral sporangia** and the zoospores, **neutral zoospores,** as they give rise to the same generation (sporophyte) instead of the alternate generation (gametophyte).

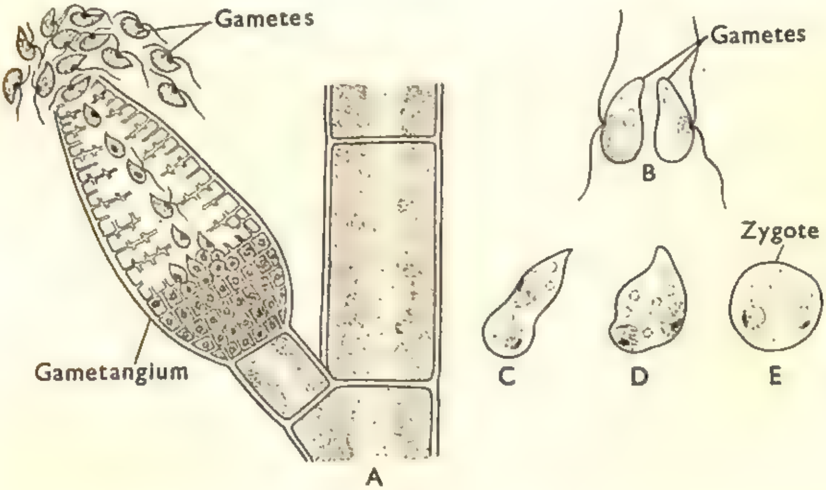


Fig. 93. *Ectocarpus.*
A, A gametangium liberating gametes; B—D, Stages in the union of gamates; E, A zygote.

Sexual reproduction takes place by the fusion of physiologically different isogametes produced within multilocular gametangia borne by the gametophytes.

The structure and mode of development of these gametangia are similar to those of the neutral sporangia borne by the sporophytic plant. Each protoplast of a gametangium develops into a biflagellate gamete. The gametes are similar to zoospores* and fusion occurs only between the gametes from separate gametophytic plants (heterothallic), which are often interpreted as sexually distinct. The diploid zygote, thus formed as a result of union of gametes, germinates and forms the sporophytic plant (diploid).

In the life cycle of an *Ectocarpus* there is an alternation of a distinct haploid generation of sexual plants bearing male and female gametes respectively and a generation of diploid asexual plant producing the zoospores.

*In *E. secundus* two types of gametangia—micro- and mega-gametangia are produced liberating gametes of unequal sizes.

Sometimes the gametes may develop parthenospores which give rise to new gametophytes.

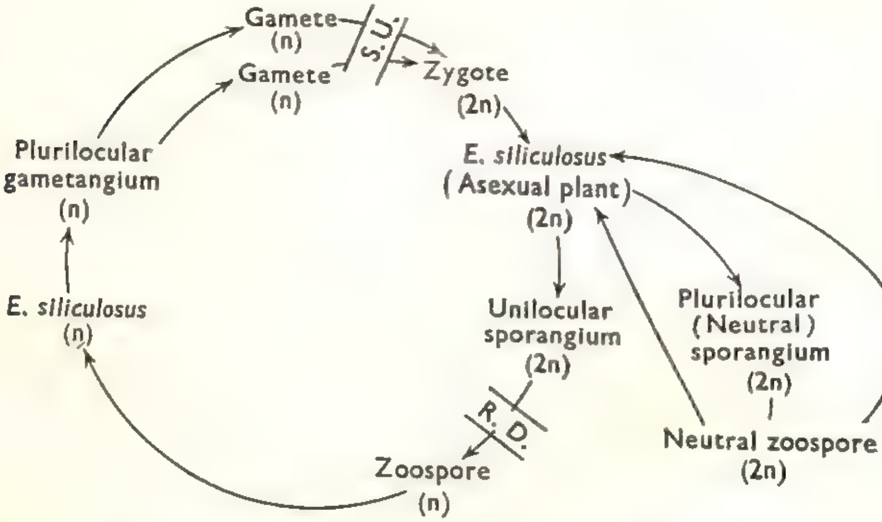


Fig. 94. Life cycle of *Ectocarpus siliculosus.*

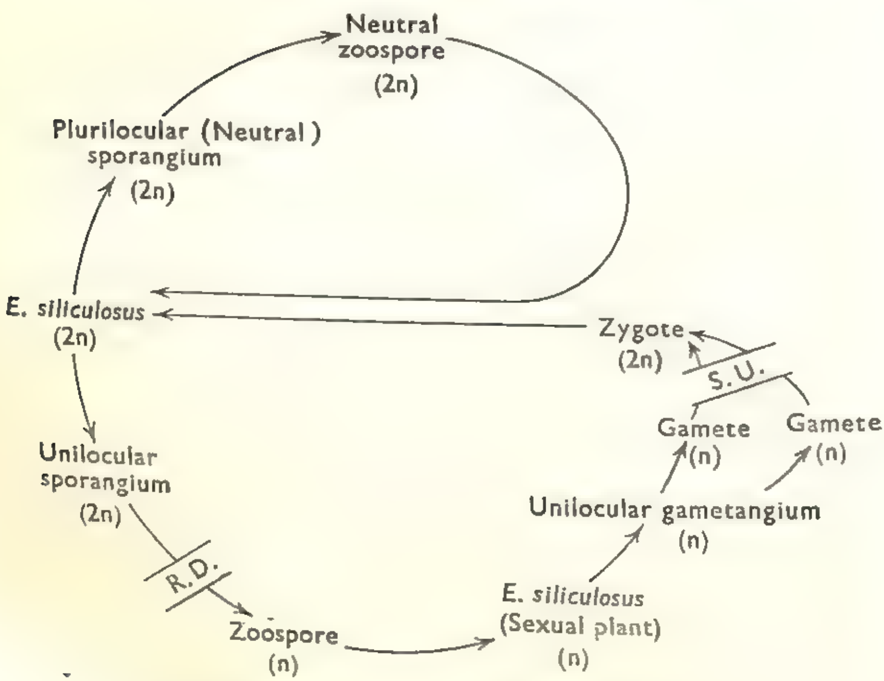


Fig. 95. Another type of life cycle of *Ectocarpus siliculosus.*

ORDER 6. **LAMINARIALES**

Plants bulky, body truly parenchymatous ; asexual reproduction by zoospores formed within unilocular sporangia ; sexual reproduction distinctly oogamous.

LAMINARIA

(Fam. LAMINARIACEAE)

Laminaria grows along the coasts of Europe, America, Africa,

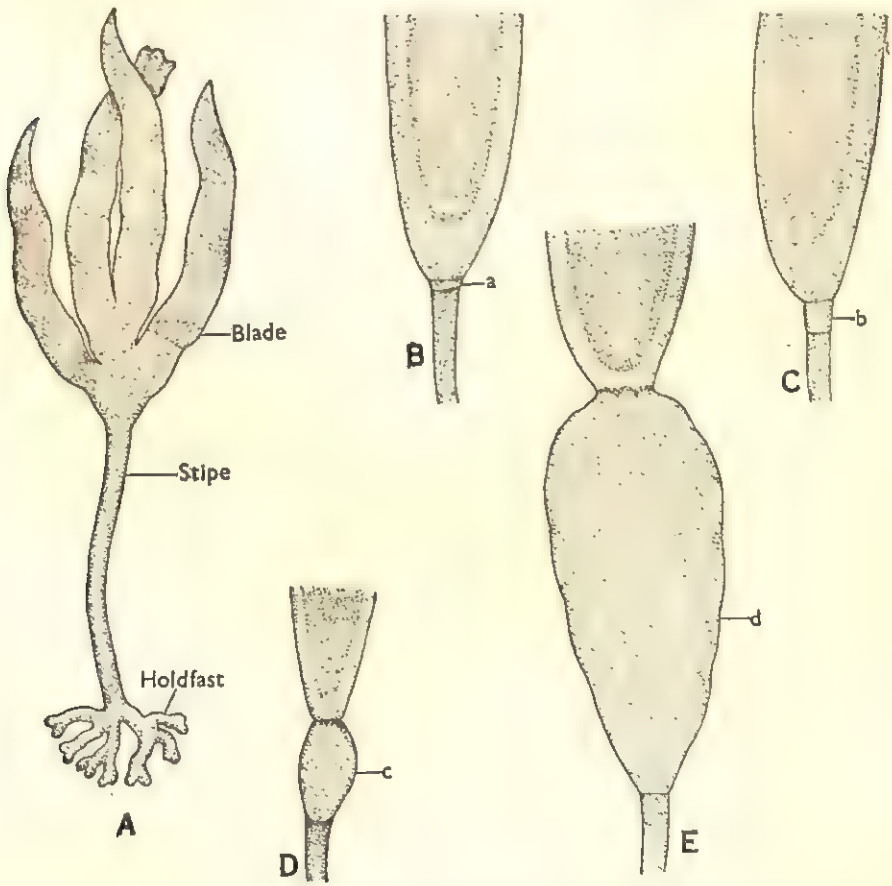


Fig. 96. *Laminaria.*
A, A sporophytic plant; B—E, Stages in the development of a new blade.

China, Japan and Russia, usually in the subtropical regions.

Majority of the species are perennial lithophytes (having their blades annual), generally forming a dense belt slightly below the low-tide limit in quieter water.

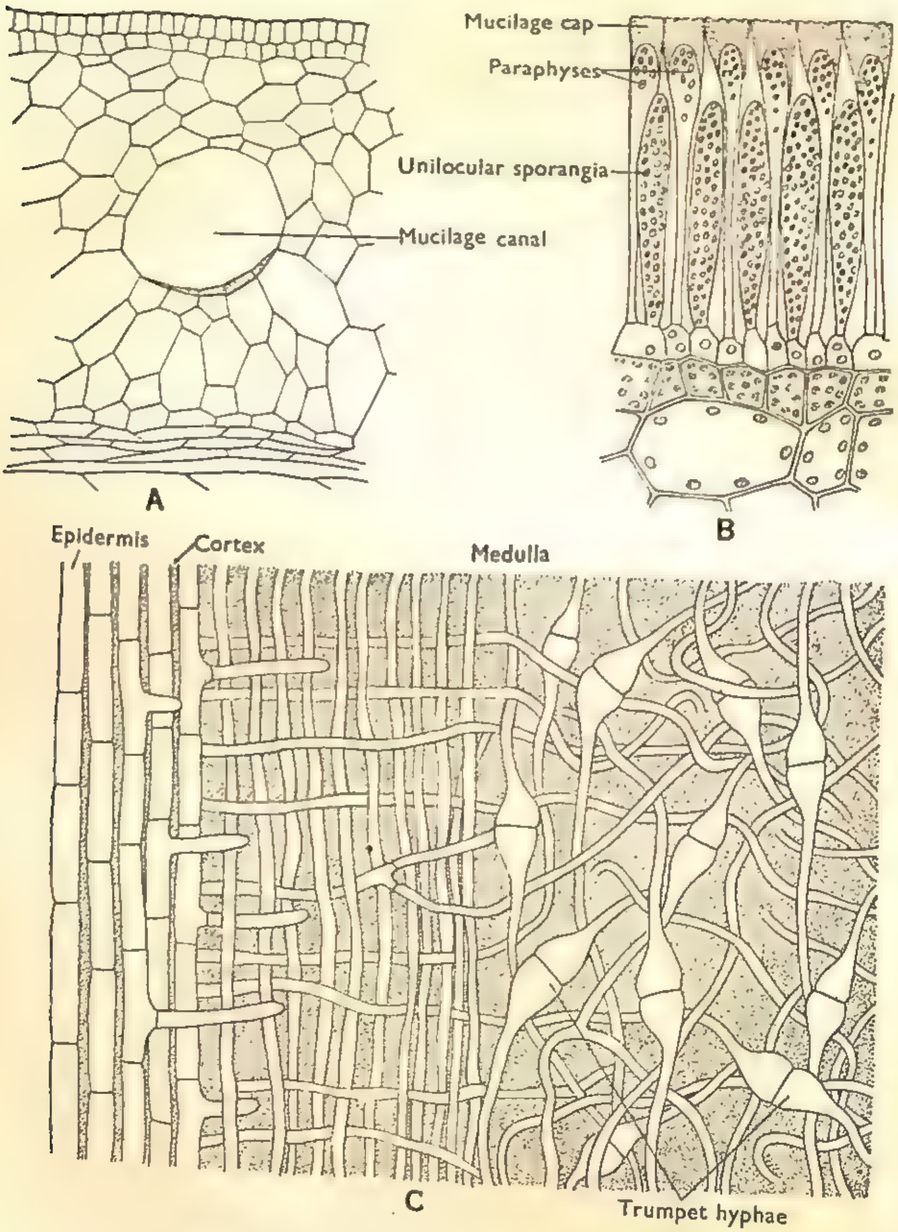


Fig. 97. *Laminaria*.
A, T.S. of a blade (in part); B, T.S. through a sorus (in part); C, L.S. through a part of the medulla of the stipe.

Vegetative body

The sporophytic plant body is differentiated into (*a*) a simple, or incised, smooth and flat or highly convoluted, leathery **blade** about 2-4 metres in length, (*b*) an unbranched and usually cylindrical **stipe,** and (*c*) a **holdfast;** the holdfast is usually an elaborate structure and is composed of a number of branched root-like bodies, called **haptera.** The growth of the sporophyte takes place with the help of an intercalary meristem situated at the junction between the blade and the stipe. This meristem not only helps both the blade and the stipe to grow in length, but also gives rise to a new blade to replace that of the last season. The newly formed blade at first appears as a small widening at the top of the stipe, separated from the previous year's blade by a prominent constriction. This new blade then goes on enlarging by a prominent constriction. Then the new blade goes on enlarging and the older one undergoes decay, remains attached to its apex as a mere appendage for some time, and finally breaks off from it.

Internally, the blade and the stipe are alike in structure. In each case, three distinct zones, the **epidermis,** the **cortex** and the **medulla,** can be differentiated although these tissues are more clearly marked off in the stipe than in the blade. The epidermal zone (the epidermis as well as the outermost cortical cells) is assimilatory in function. The cells of the medulla are highly modified, particularly in respect of certain cells which stop dividing early and are drawn out into long attenuating filaments, which maintain their original breadth near the transverse walls. These are known as the **trumpet hyphae** and are comparable to the sieve tubes of the higher plants. They also possess some spiral bands of thickening matters of cellulose on their walls. The real function of these trumpet hyphae is yet unknown. A system of anastomosing **mucilage canals** is noted in the cortex.

Reproduction

Laminaria reproduces both by asexual and sexual methods.

Asexul reproduction takes place by unilocular sporangia which are borne in widely extended **sori** on both the surfaces of a blade and, as a rule, formed at a specific season, either during the summer or in the early autumn. The sporangia lie in between the unicellular, club-shaped **paraphyses,** which form a palisade-like layer; at the top of each paraphysis there is a prominent **mucilagenous cap,**

and the caps of all the paraphyses in a sorus remain attached together keeping the sorus firm. The single nucleus of the sporangium, dividing meiotically, gives rise to 32-64 nuclei, each of which along with a little amount of cytoplasm is ultimately metamorphozed into a pear-shaped, biflagellate zoospore. The zoospores are liberated through the apex of the sporangium enclosed in a sheath, which persists for a very short time and finally dissolves away leaving the zoospores swimming freely. After swimming for some time, each zoospore comes to rest, rounds up, secretes a wall around it and very quickly puts forth a germ tube. About half of the total number of zoospores develop into male plants and the other half, into female ones.

Both the gametophytic plants are filamentous in nature and are composed of a number of cells, which are rather smaller in size in case of the males than in the females.

The sex organs are produced on the lateral branches of the thallus. The antheridium is a small, somewhat spherical, single cell whose

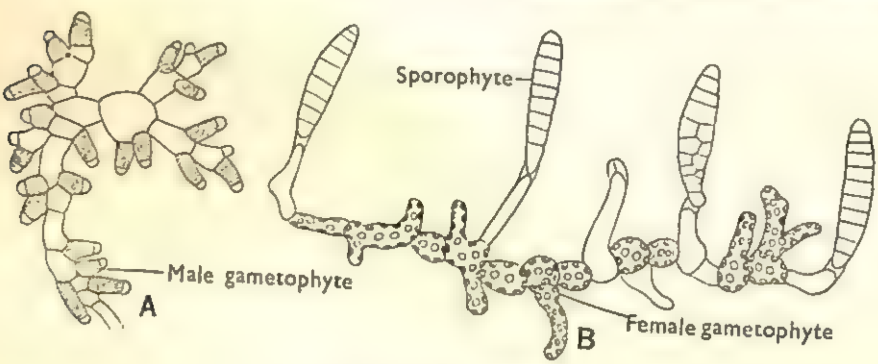


Fig. 98. *Laminaria.*
A—B, The two types of gametophytes.

protoplast is metamorphozed into a single antherozoid provided with two long, unequal, laterally inserted flagella. The oogonium gives rise to a single egg, which on maturity is extruded out through the apical pore of the oogonium but remains attached to it. Fertilization takes place in the usual way by the union of the two gametes, and thus an oospore is formed. An oospore on germination gives rise to a new sporophyte. An egg which fails to get fertilized may develop into a sporophyte parthenogenetically.

The life cycle of *Laminaria* exhibits heteromorphic alternation of the two generations.

Economic importance

Laminaria is a good source of the polysaccharide 'laminarin'. Formerly, the plant was extensively used for the production of iodine. It is also used as a diet under the name 'Kombu' by the Japanese. The Chinese as well as the Russians also use it as a food.

ORDER 8. DICTYOTALES

Plants with frequent dichotomous branching and slightly differentiated parenchymatous forms ; asexual reproduction by non-motile tetraspores formed within unilocular sporangia ; sexual reproduction oogamous.

DICTYOTA

(Fam. DICTYOTACEAE)

Dictyota, a cosmopolitan species, is widely distributed in the tropical seas. It grows along the shores in the intertidal zones, usually attached to the rocky substratum by a disc-shaped holdfast. The most common species, *D. dichotoma*, is an annual.

Vegetative body

The plant body is a regularly, dichotomously branched, flat, membraneous, frond-like thallus, which spreads out in a more or less fan-shaped fashion from a comparatively narrow, cylindrical base with a holdfast; the holdfast remains attached to the substratum with the help of rhizoids. The entire plant grows by means of a single apical cell.

Internally, a thallus consists of three layers, a central one (**medulla**) composed of large-sized cells, and an upper and a lower **epidermal layers,** which are made up of smaller cells containing chromatophores; groups of mucilage hairs arise from these epidermal layers.

Reproduction

Dictyota reproduces by vegetative, asexual and sexual methods.

Vegetative reproduction may take place by the decay of the older parts of the thallus, followed by subsequent fragmentation. In some cases, specially modified structures, called **gemmae** or

brood buds, are developed on the body of the thallus for the purpose.

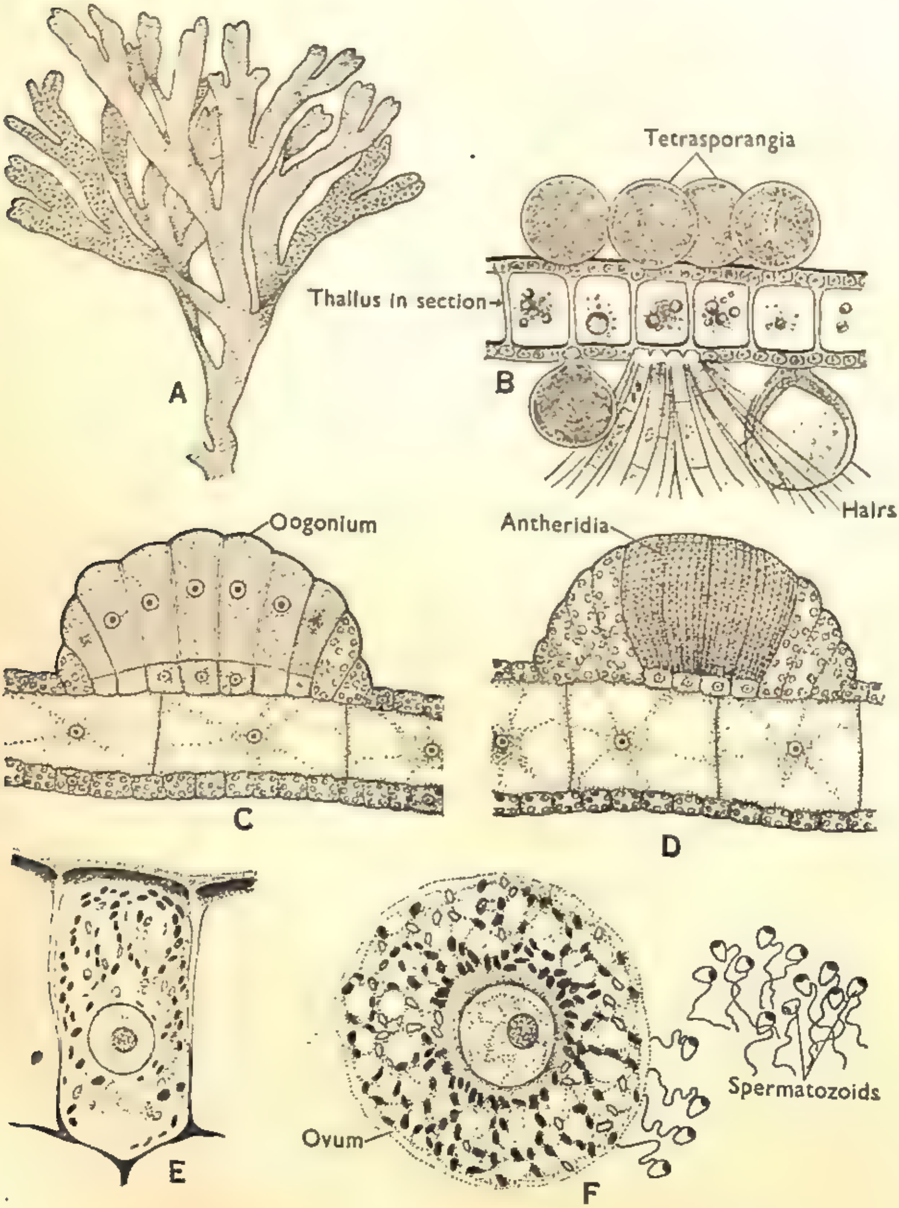


Fig. 99. *Dictyota*.
A, An entire plant; B, Section of the thallus showing tetrasporangia; C, V.S. through oogonial sorus; D, V.S. through antheridial sorus; E, Rudiment of an young oogonium; F, An egg during fertilization.

Asexual reproduction takes place with the help of large, non-motile spores, called **tetraspores.** The tetraspores are produced inside **tetrasporangia,** which are usually grouped together forming ill-defined **sori** on both the sides of the thallus. The tetrasporangia are without any involucral covering and are produced on diploid asexual plants only. The solitary nucleus of a tetrasporangium undergoes a reduction division and gives rise to four, slightly elongated, naked tetraspores, each having a haploid set of chromosomes. On maturity, the tetraspores come out through an apical opening on the tetrasporangial wall and germinate directly giving rise to male and female sexual plants in equal proportions, which are morphologically alike with the asexual plants. In some cases, a tetrasporangium may fail to produce tetraspores, and then it germinates quickly and reduplicates the same diploid generation.

Sexual reproduction is oogamous. The gametophytes are normally heterothallic. The sex organs are differentiated in groups of sori on the male plants, each sorus being enclosed by a well-defined involucre (a sterile jacket layer of cells). Each white and glistening antheridial sorus consists of about 100-200 antheridia, and each antheridium forms about 1500 uniflagellate sperms. The oogonial sori are deep brown in colour and are also invested by individual rudimentary involucre. Each oogonial sorus contains about 25-50 oogonia, each producing a single egg. On maturity, the apex of the oogonium becomes gelatinized and dehisces, thereby liberating the egg. There is a marked periodicity, usually corelated with the fortnightly sequence of spring and neap tides of the lunar month, in the development of sex organs and gametes. When sperms and eggs are discharged in sea water, the latter secrete a substance which attracts the sperms and fertilization is effected very soon (often in course of half an hour's time). The fertilized egg or oospore readily germinates into a diploid asexual plant. In rare cases, an unfertilized egg secretes a wall around it and germinates parthenogenetically.

It is to be noted that *Dictyota* possesses an isomorphic alternation of generations.

ORDER 9. **FUCALES**

Plants with parenchymatous forms and complex external and

internal differentiations ; asexual reproduction unknown ; sexual reproduction oogamous.

FUCUS

(Fam. FUCACEAE)

Fucus, the best known brown alga, is widely distributed and is an inhabitant of salt water along the coasts of the oceans of the temperate and colder zones. Most of the species grow permanently attached to rocks between the high and low tide levels, and are

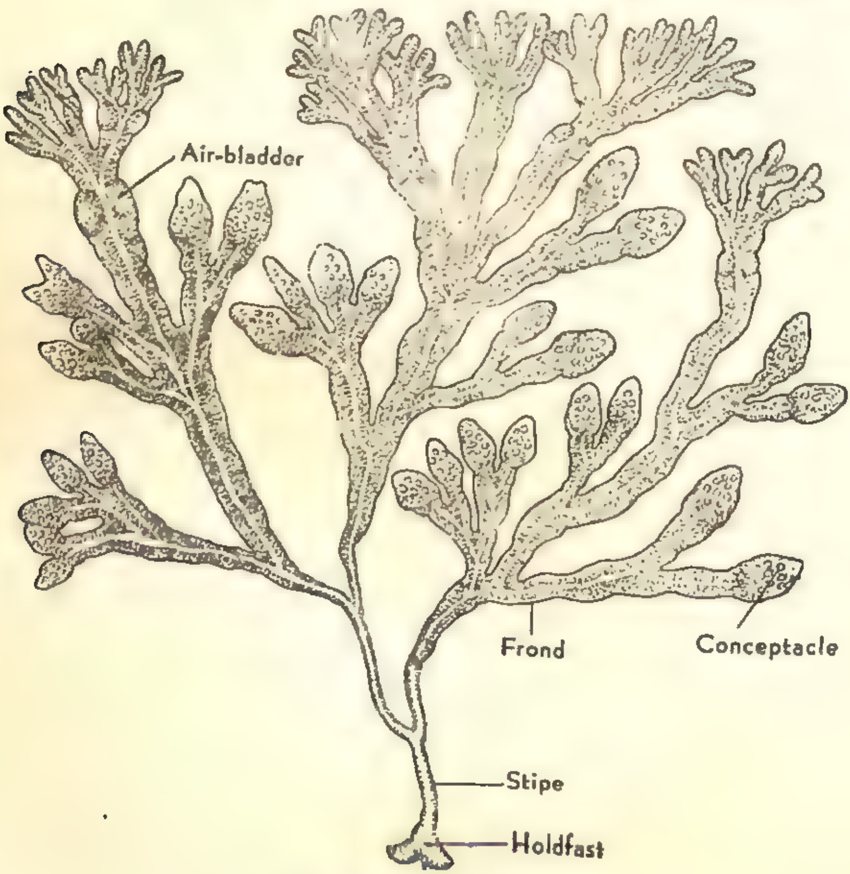


Fig. 100. *Fucus vesiculosus.*
A mature thallus with swollen ends of the branches containing conceptacles, in which sex organs are formed.

often torn loose by storms and carried hundreds of miles away into the sea.

Vegetative body

The thallus, which is a sporophyte, shows the greatest complexity of form with an external differentiation comparable to that of a vascular plant. It has a disc-like **holdfast** from which arises a stem-like **stipe** , that bears a broad leaf-like flattened portion, the **frond.** The plant as a whole is about 35-70 centimetres long, and the leafy portion of the thallus shows regular dichotomous branching. As the plant grows the fronds may fork repeatedly.

The thalli of some species of *Fucus* (*e.g.*, *F. vesiculosus*) contain, a little behind the apices of the branches, **air-bladders,** which are formed due to the accumulation of gas in large intercellular spaces, and these help the plants to keep erect when they are submerged under water.

A cross section of the thallus shows that it is internally differentiated into two distinct tissues : (1) the central **medulla** composed of loose mass of colourless elongated cells, and (2) the surrounding **cortex** forming a compact dark brown outer region, made up of more or less isodiametric cells, which contain chromatophores towards the periphery. The protoplast of the vegetative cell is vacuolated and usually contains a single nucleus having a nuclear membrane, a nucleolus and a chromatin network. There are usually more than one chromatophores without any pyrenoid.

Reproduction

Fucus always reproduces by the sexual method, and the gametic union is of an oogamous type. Though a sporophyte, it bears gametangia, antheridia and oogonia, within spherical chambers, called **conceptacles.** At maturity, the tips of the branches become swollen in which these conceptacles are embedded, and these appear as warty elevations on the surface even when viewed without a lens. A mature conceptacle is globose and opens at the surface by a small pore, the **ostiole.** Numerous slender multicellular unbranched hairs, called **paraphyses,** grow out from the inner surface of the conceptacle; these are usually directed towards the ostiole. Some unbranched hairs may grow out through the ostiole forming cottony tufts, and are then known as **periphyses.**

The common eastern species, *Fucus vesiculosus*, is heterothallic, since some plants have conceptacles containing only antheridia, while other plants contain only oogonia. But in some species, the

antheridia and oogonia may be produced within the same conceptacle.

The antheridia, at the beginning, are ovoid cells, which are produced on much-branched hairs and are associated with the paraphyses within the antheridial or mixed conceptacles. Each of these ovoid cells, which is destined to develop into an antheridium, is uninucleate, and this nucleus divides and re-divides until 64 nuclei are produced, the first nuclear division being reductional*. Ultimately, each nucleus, with some amount of cytoplasm becomes

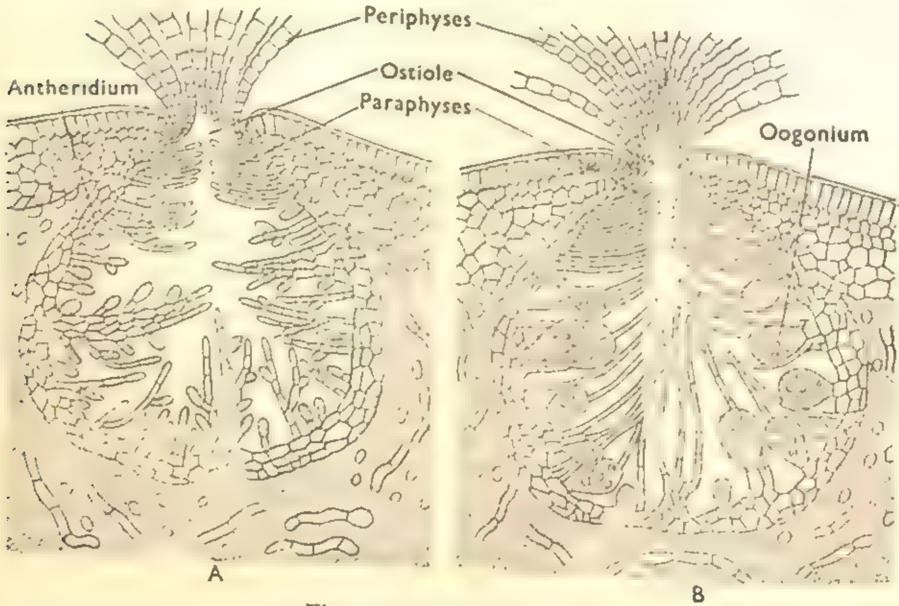


Fig. 101. *Fucus vesiculosus.*
A, Part of cross section of the thallus through a male conceptacle containing antheridia; B, The same through a female conceptacle containing oogonia.

more or less pear-shaped antherozoid with two laterally attached flagella of unequal lengths and an eyespot. At maturity, the wall of the antheridium ruptures, and the whole mass of antherozoids within it escapes and is lodged in a considerable amount of mucilage secreted by the paraphyses for the purpose. The *Fucus* plant, when exposed to air during low tide, undergoes shrinkage, and as a result, the mass of gametes, embedded in the mucilage, is extruded

*It is to be noted that the development of the antherozoids is similar to that of the zoospores within the unilocular sporangia produced on the sporophyte of *Ectocarpus*, and that in this case the spores produced by the unilocular sporangia function as gametes.

through the ostiole. At high tide these are washed off and the antherozoids are set free for fertilization.

The oogonia are also produced among the paraphyses within the oogonial or mixed conceptacles. During the development of an oogonium, a short outgrowth develops from the layer of cells forming the wall of the conceptacle. This outgrowth divides transversely into two cells, the distal one becomes the oogonium while the basal one is called the **stalk cell.** The oogonial cell,

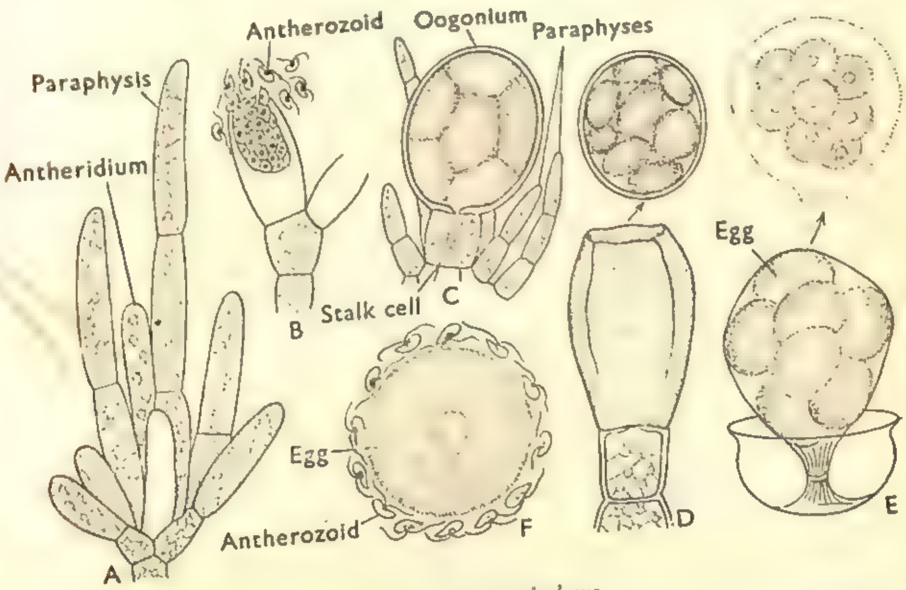


Fig. 102. *Fucus vesiculosus.*
A, An antheridial branch with antheridia; B, Liberation of antherozoids; C, The oogonium; D, Oogonium from which a group of eight eggs still enclosed within the inner oogonial walls is escaping; E, Later stages of the same; F, An egg surrounded by numerous antherozoids.

densely filled with cytoplasm, is uninucleate, and as it enlarges the nucleus divides by three successive divisions forming eight daughter nuclei, the first division being always reductional. This is followed by the division of the cytoplasm into eight uninucleate masses, each of which becomes rounded and forms an egg. The oogonial wall becomes differentiated into two relatively firm layers, separated from each other by a softer gelatinous layer. When the eggs become mature, the outer wall ruptures. The eight eggs escape from the outer wall of the oogonium being still enclosed by the two

inner walls, and are pushed outwards and finally through the ostiole. These two inner layers also rupture in succession, and the eggs are finally extruded into the sea where fertilization takes place.

The fertilization of the eggs outside the body of the plant is made possible by reason of the great number and motility of the antherozoids, as well as, due to the characteristic smell of a substance secreted by the egg by which the antherozoids are attracted. Each fertilized egg then secretes a thin cellulose wall around it forming a zygote, and this does not become a resting spore. It soon germinates and grows into a new plant.

The life history of *Fucus* does not represent a regular alternation of generations. The plant is the sporophyte having the double or $2n$ number of chromosomes (diploid). The haploid number (*i.e.*, n) is found in the gametes (antherozoids and eggs), and this is brought about during the first division of the nuclei of antheridial and oogonial cells as a result of reduction division. The return to the diploid phase is soon accomplished by the union of the gametes and with the formation of the zygote, which develops into the sporophytic plant.

SARGASSUM

(Fam. SARGASSACEAE)

Sargassum, or gulf weed, chiefly occurs in the warmer seas of the Southern hemisphere, though a few species may be found in the Mediterranean sea. Huge floating masses of various species of *Sargassum* are found in the Sargossa sea, off the coast of Africa. In India, different species of the genus are found to be growing in the Bay of Bengal, in the Malabar coast of the Arabian Sea, and in the Indian ocean.

Vegetative body

The plant body has a main axis with lateral branches, which are highly branched in their turn; the branching is always monopodial. The lateral branches, both primary and secondary, are of limited growth bearing at their bases one or two leaf-like structures, each of which is provided with a distinct midrib and somewhat serrated margins, and bears the rest of the entire system in its

'axil'. The lowest member or members of this branch system, or the subtending leaves, usually form the stalked **air-bladders,** which are undoubtedly the homologues of 'leaves'. Though for the sake of convenience the terms 'leaves' and 'axillary branches' are frequently used, yet the entire structure represents a single branch system only.

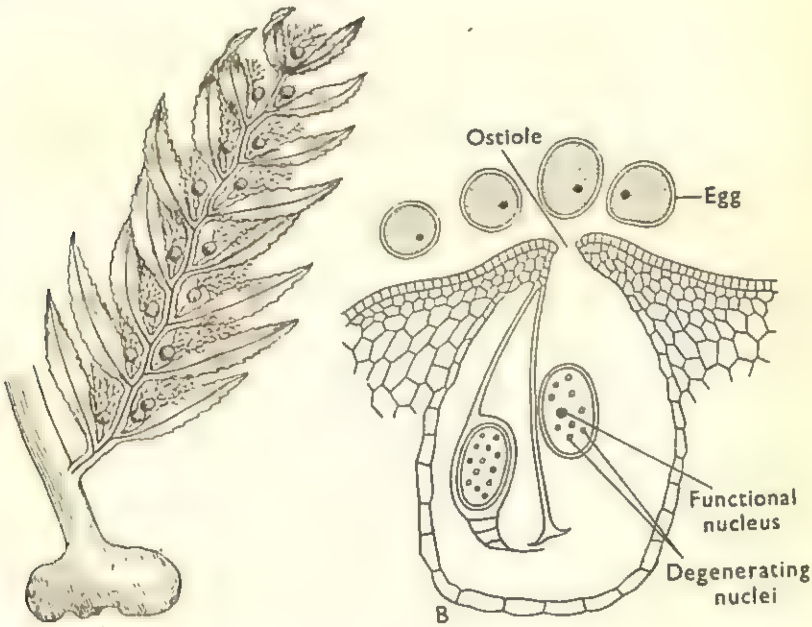


Fig. 103. *Sargassum*.
A, A portion of the plant body; B, Cross section of the thallus through a female conceptacle containing eggs.

The surface of the axis is covered by a cuticle. At the peripheral region there are somewhat palisade-like cells containing chromatophores. The cells of the cortex are somewhat elongated and thick-walled, while those of the medulla are narrow, elongated, and partly thin-walled and partly thick-walled. All the cells are uninucleate.

Reproduction

Sargassum reproduces by the sexual method only.

The sex organs are borne within the **conceptacles,** scattered over

the surface of the thallus and lying intermingled with some sterile conceptacles or **cryptoblasts.** The plants may be homothallic or heterothallic. In the former case, both the male and female conceptacles are found to be growing on the same thallus, although occasionally hermaphrodite conceptacles may be found. From the walls of fertile conceptacles, branches bearing antheridia or oogonia come out, along with some sterile branches or paraphyses.

The antheridia are cut off at the tips of branched thread-like structures from small stalk cells. During the early stages of development, each antheridium possesses a diploid nucleus, which, with the maturation of sex organs, divides reductionally, and is subsequently followed by a number of mitotic divisions giving rise to 32 or 64 nuclei. Now cleavage of the cytoplasm takes place forming 32 or 64 biflagellate antherozoids. These antherozoids are liberated in a mass, enclosed within a fine envelope, and come out into the water through the ostiole. This envelope soon disappears in water and the gametes are set free.

The oogonia are borne on short stalk cells developed from the wall of the conceptacle, and appear to be partially embedded in the wall. The nucleus of a young oogonium is also diploid, and as the oogonium matures the nucleus undergoes three divisions, one of which is reductional, forming eight daughter nuclei. Out of these eight nuclei, seven degenerate *in situ*, while around the eighth one an egg is formed, which is liberated out into the water.

Fertilization takes place in the usual way in sea water giving rise to an oospore. The oospore finally develops into a new plant.

The life cycle of *Sargassum*, as in *Fucus*, does not exhibit a regular alternation of generations.

CLASS X. RHODOPHYCEAE

Salient features

The Rhodophyceae, or the red algae, are readily distinguished from other algae by the following salient characters : (*a*) presence of chromatophores with a red pigment, **phycoerythrin,** in addition to the usual photosynthetic pigments and rarely with a blue pigment, **phycocyanin ;** the presence of phycoerythrin in a large quantity often gives the plant a distinctive red colour, though green, olive-green and golden brown red algae are not uncommon ; (*b*) total lack of flagellate asexual spores; (*c*) transportation of non-flagellate male gamete to the female sex organ, the **carpogonium,** and deposition against it at the time of sexual reproduction; (*d*) indirect formation of spores mostly takes place from the zygote, but in some cases the zygote directly divides to form spores.

General characters

A great majority of red algae are strictly marine, but freshwater species are not uncommon. The former are found in all oceans including the Arctic and Antarctic oceans where the number of species is very few. They usually occupy the intertidal or littoral zones, but there are some which grow at levels never exposed by tides. These latter species usually grow in association with Chlorophyceae and Phaeophyceae. The greatest depth at which Rhodophyceae occur has been reported to be 200 metres. The majority of the marine Rhodophyceae are normally sessile, and grow upon rocks or some other inanimate substratum. Some species grow upon other Chlorophyceae, Phaeophyceae and Rhodophyceae, either as epiphytes or as true parasites, being mostly restricted to a single host. The sessile species, when become detached and free-floating, soon die.

In great majority of cases, there is a single, large vacuole in each cell, and the protoplasm usually forms a thin lining layer just internal to the cell wall. The cell wall is made up of cellulose and various other pectic compounds. In most cases a pore-like opening is found in the wall between adjacent cells, through which broad cytoplasmic strands connect the two protoplasts. The vegetative cells are mostly uninucleate, but in some multinucleate ones the number of nuclei may go upto three to four thousands in each cell. Each resting nucleus possesses a well-defined nuclear membrane, a conspicuous nucleolus, and an intervening hyaline zone. In each vegetative cell of the primitive red algae there is a single, centrally located, star-shaped chromatophore with a central pyrenoid without any starch sheath. In more advanced species, they are disciform without pyrenoids, and are usually more than one in each cell. Carbohydrate food reserves are found in the form of small grains, known as **floridean starch,** distributed in the general mass of cytoplasm outside the chromatophores. The floridean starch is an intermediate product between starch and dextrin, and when treated with iodine solution, becomes light brown or wine-red in colour. Besides a soluble sugar, **floridoside,** often accumulates.

The chromatophores of red algae contain the same photosynthetic pigments (chlorophyll *a*, chlorophyll *b*, carotene and xanthophyll), but the relative proportion is different from that in the higher plants. In addition to these, a water-soluble red pigment, **phycoerythrin,** is always present. Besides, in some species a blue pigment is also

present, and this pigment resembles the phycocyanin of Myxophyceae.

A high light intensity increases the rhodophycean phycocyanin (*r*-phycocyanin) formation, and retards the development of phycoerythrin. The function of *r*-phycocyanin is not yet known, while that of phycoerythrin also remains a debatable point. It is generally believed that phycoerythrin functions as a photosynthetic pigment in blue light, and thus enables the deep water Rhodophyceae to carry on with their photosynthesis. Some workers are of opinion that the deep red colours of some members of this group are due to the absence of *r*-phycocyanin with a corresponding presence of a high percentage of phycoerythrin, and other shades of colour are due to an increasing proportion of *r*-phycocyanin. The great diversity of shapes and colours in Rhodophyceae is obviously due to the variation in the component ratio of these pigments.

With the exception of two genera, the thallus of Rhodophyceae is multicellular. This multicellular thallus may be a simple, branched filament made up of a row of cells, or it may assume a complex body of definite macroscopic form. The complex types usually attain a height of 10 cm., but may be more than a metre in a few cases.

Reproduction

Red algae seldom reproduce vegetatively. Vegetative reproduction may take place by the fragmentation of the thallus.

Asexual reproduction takes place by one or more types of non-flagellate asexual spores.

In the sexual reproduction, the male sex organ (**spermatangium**), and the female sex organ (**procarp** or **carpogonium**) are produced, either on the same plant or on different plants. The male gamete (**spermatium**) is produced from the spermatangium, and its nucleus fuses with the carpogonial nucleus to give rise to the zygote nucleus.

Alternation of generations

In the Subclass Bangioideae, there is no definite alternation of generations. On the other hand, the Subclass Florideae is characterized by having a regular alternation of generations, which may be either **biphasic** or **triphasic.** In the former case, the sexual

generation or the gametophyte alternates with the asexual one or the carposporophyte. The gametophyte is invariably haploid, but the carposporophyte may be either haploid or diploid. In the latter case, *i.e.*, in case of triphasic life cycle, there are three generations—the haploid gametophyte, the diploid carposporophyte, and the diploid tetrasporophyte which follow one another in regular succession.

Classification

The Rhodophyceae has been divided (Fritsch, 1935) primarily into two Subclasses, one having only *one* Order under it, while the other possesses *six* Orders. A brief outline of the classification is given below.

I. Subclass Bangioideae

Plants simple, filaments never aggregated; no pit-connections between the cells; very little specialization of sex organs; direct division of the zygote gives rise to carposporangia; terrestrial, freshwater, and marine.

Order Bangiales. Plants ranging from unicellular to parenchymatous forms; accessory reproduction by means of monospores; life cycle haplobiontic. Examples—*Compsopogon*, *Porphyra*, etc.

II. Subclass Florideae

Plants usually filamentous with aggregation of filaments forming pseudo-parenchymatous thalli; cells with pit-connections; sex organs clearly differentiated; gonimoblast filaments bearing carposporangia formed directly or indirectly from zygote; mainly marine.

Order 1. Nemalionales. Plants filamentous; construction of thallus uniaxial or multiaxial; accessory reproduction with the help of monospores or tetraspores; life cycle haplobiontic; some forms freshwater. Example—*Nemalion*, *Batrachospermum*, etc.

***Order 2. Gelidiales.** Plants filamentous; uniaxial; generally with cruciate tetrasporangia; life cycle probably diplobiontic. Example—*Gelidium*.

***Order 3. Cryptonemiales.** Plants filamentous; uniaxial or multiaxial; tetraspores zonate or cruciate; some special fertile areas (conceptacles, nemathecia) noted in some cases; life cycle diplobiontic. Examples—*Cryptosiphonia*, *Corallina*, *Lithothamnion*, etc.

* Not treated in this book.

*Order 4. Gigartinales.** Plants filamentous; uniaxial or multiaxial; tetraspores zonate or cruciate; life cycle diplobiontic. Examples—*Agardhiella, Iridea*, etc.

***Order 5. Rhodymeniales.** Plants filamentous; multiaxial; tetraspores tetrahedral or cruciate; life cycle diplobiontic. Examples—*Rhodymenia, Gastrodonium, Champea*, etc.

Order 6. Ceramiales. Plants filamentous; uniaxial; tetraspores generally tetrahedral; carpogonial branch 4-celled; life cycle diplobiontic. Examples—*Ceramium, Callithamnion, Polysiphonia*, etc.

SUBCLASS I. BANGIOIDEAE

Plants simple, filaments never aggregated ; no pit-connections between the cells ; very little specialization of sex organs ; direct division of the zygote gives rise to carposporangia ; terrestrial, freshwater, and marine.

ORDER BANGIALES

Plants ranging from unicellular to parenchymatous forms ; accessory reproduction by means of monospores ; life cycle haplobiontic.

*COMPSOPOGON***

Compsopogon is a freshwater alga, commonly occurring in bunches in tropical and subtropical streams, and occasionally along the embankments of ponds, attached either to some submerged parts of aquatic plants, or to the mud below the water level.

The common Indian species of *Compsopogon* are *C. coeruleus* and *C. lividus.*

Vegetative body

The plant body is highly branched, filamentous and coarse, and with a blue- or violet-green colour. The primary filament, after attaining a certain amount of length, begins to give rise to lateral branches forming angles with the parent axis. The mode of

* Not treated in this book.

** *Compsopogon* is a member of doubtful systematic position. Fritsch does not include it either under the Family Bangiaceae nor under the Family Porphyridiaceae. Smith, however, places it under the Family Erythrotrichiaceae.

branching is very regular in *C. coeruleus*, whereas it is extremely irregular in *C. lividus*. So long as the primary filament as well as its

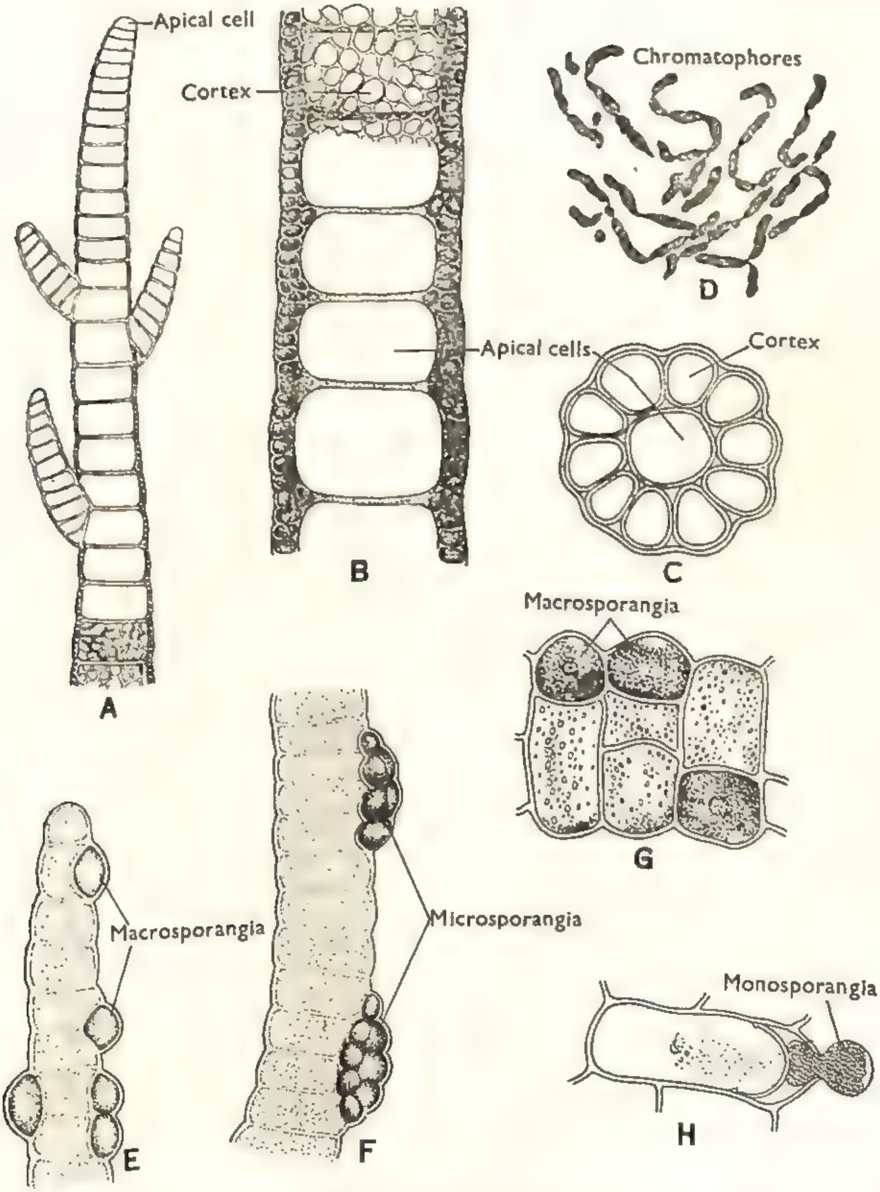


Fig. 104. *Compsopogon*.
A, A portion of the plant body; B, A portion of an old filament showing the cortex and the apical cell; C, T.S. of the same; D, Chromatophores; E, A portion of the filament with macrosporangia; F, A portion of the filament with microsporangia; G, A portion of E highly magnified; H, A portion of the filament showing monosporangia.

branches remain uniaxial in construction, they are distinctly corticated at the nodes. The cells are flat and discoid (in younger parts) or barrel-shaped (in older parts), and contain many parietal or somewhat lobed chromatophores. The plant is attached to the substratum by a plate-like holdfast.

Reproduction

Compsopogon reproduces by the asexual method only, the sexual method is as yet unknown.

Asexual reproduction takes place by means of **monospores,** which are developed within the so-called **macrosporangia** and **microsporangia.** The former types of sporangia are always solitary, whereas the latter ones usually form projecting **sori.** The sporangia are hemispherical, spherical, oblong or polyhedral in shape, and may develop from any superficial cell of the cortex in older regions, or from any cell of the axial row in the younger regions. The entire protoplasmic content of a sporangium may be transformed into a single monospore or a number of monospores, and are liberated apparently enclosed in a slimy envelope. Each monospore is round, naked and motionless, with a prominent nucleus and dense contents, and on germination gives rise to a new plant.

SUBCLASS II. FLORIDEAE

Plants usually filamentous with aggregation of filaments forming pseudo-parenchymatous thalli; cells with pit-connections; sex organs clearly differentiated; gonimoblast filaments bearing carposporangia formed directly or indirectly from zygote; mainly marine.

ORDER 1. NEMALIONALES

Plants filamentous; construction of thallus uniaxial or multiaxial; accessory reproduction with the help of monospores or tetraspores; life cycle haplobiontic; some forms freshwater.

BATRACHOSPERMUM

(Fam. Batrachospermaceae)

Batrachospermum, a simple red alga, grows generally in temperate and tropical climates in rapidly flowing streams or in cold springs,

being attached to the stones, pebbles or woodwork during spring and summer. Sometimes it also occurs in lakes upto a depth of 50 metres.

The most common Indian species of *Batrachospermum* is *B. vagum*.

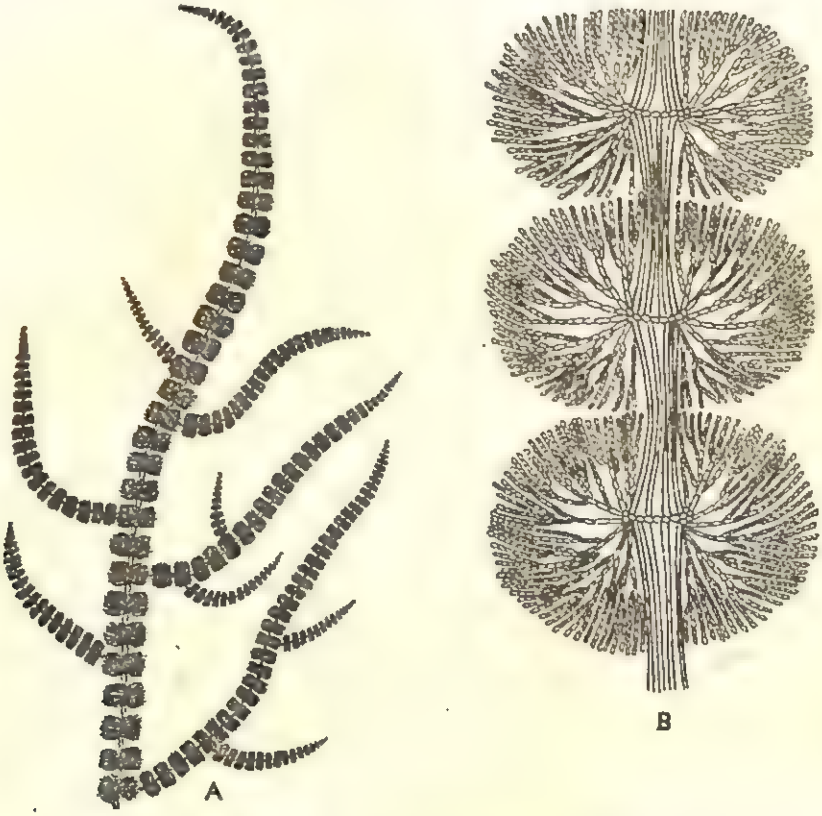


Fig. 105. *Batrachospermum*.
A, A portion of the thallus showing the general habit;
B, Three whorls of the thallus enlarged.

Vegetative body

The plant is characterized by having a thallus body of delicate, freely-branched, filiform filaments, varying in size from a few to several centimetres in length. The branches are usually moniliform, and have a gelatinous consistency. Its colour varies from bluish-green to olive-green, but may be of violet or reddish tint when it grows in deep water under shady places. The older portions of the

thallus are made up of large cells arranged in an axial row bearing numerous vertical branches, which are either simple or divided in a forked manner, and the lateral branches are repeatedly forked. The lateral branches usually occur in the form of globose clusters at the nodes imparting to the plant its characteristic beaded appearance, and these may lie quite close to or a little distance apart from one another. From the basal cell of the lateral branches threads also grow downwards covering the external surface of the large axial row of cells, ultimately forming a complete cortex-like sheath. The protoplast of each cell is uninucleate, and contains several discoid or elongated chromatophores, each with a pyrenoid.

Reproduction

Batrachospermum reproduces both asexually and sexually.

Asexual reproduction always takes place in the young gametophytes by the production of **monospores,** developed singly within sporangia, called **monosporangia.** But in some species, they may also develop terminally on short lateral branches of the adult plant. The monosporangium is a globose structure, which differs in shape from the vegetative cell. The monospore is discharged from the monosporangium as a naked amoeboid protoplast, which finally comes to rest, secretes a wall around it, and directly gives rise to a new plant.

The plants are gametophytes, which may be either homothallic or heterothallic. The **carpogonium,** or the female sex organ, develops terminally on a few-celled, short, secondary lateral branch, called the **carpogonial filament,** the cells of which have denser protoplasts and are without chromatophores. When ready for fertilization, it has a swollen base with a prominent nucleus, and a conspicuously prolonged distal portion, the **trichogyne.** The male sex organ is called the **antheridium** or **spermatangium,** which develops usually terminally on a specialized cell, the **spermatogonial mother-cell,** produced on special branches as a terminal member. Each spermatangium is uninucleate, and at maturity it becomes globose to somewhat elongated in appearance. Its protoplast, called the **spermatium,** is usually colourless, but may sometimes contain a chromatophore. The spermatium ultimately escapes by the rupture of the spermatangial wall, being still enveloped by another delicate wall whose morphological nature is doubtful.

The spermatia, after liberation, are carried away by the currents of water, and are finally lodged on the wall of the trichogyne. At the point of contact the intervening walls dissolve, and the nucleus

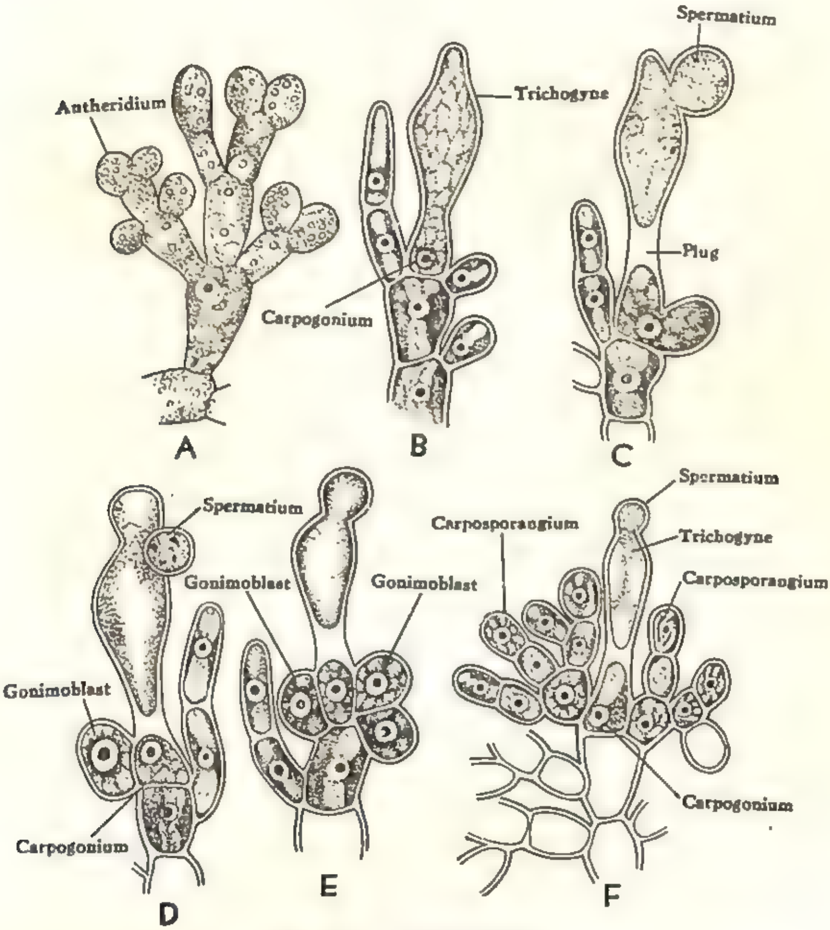


Fig. 106. *Batrachospermum*.
A, A group of antheridia; B, A mature carpogonium; C—D, Early and E, later stages of gonimoblast development; F, Mature gonimoblast with carposporangia.

of the spermatium migrates into the trichogyne, and finds its way into the base of the carpogonium, where fusion takes place between it and the carpogonial nucleus. In some cases, it has been observed that the spermatial nucleus may divide into two nuclei during its

passage into the trichogyne, and one of them fuses with the carpogonial nucleus. After fusion, the basal portion of the carpogonium becomes separated from the trichogyne by the formation of a cross wall. This is followed by an immediate reduction division of the zygote nucleus, and two daughter nuclei are formed, one of which migrates into a lateral protrusion on the wall of the old zygote, and is ultimately cut off by the formation of a wall. The remaining nucleus may divide again and repeat the same process. From these cells a mass of filaments (**gonimoblast filaments**) is produced. At the distal end of each filament a spore, called **carpospore,** is formed. This mass of filaments with the terminal carpospore and the remains of the carpogonium is called a **cystocarp.** The nuclei of the cells of these filaments and those of the carpospores are, therefore, all haploid structures. When the carpospore matures the cell wall bursts, the protoplast floats away, comes to rest, secretes a wall around it, and germinates into a simple, filamentous plant (**Chantransia stage**) from whose branches ultimately adult gametophytic plants are derived. It is to be noted that in the entire life history the zygote only represents the diploid structure, and the life cycle is biphasic.

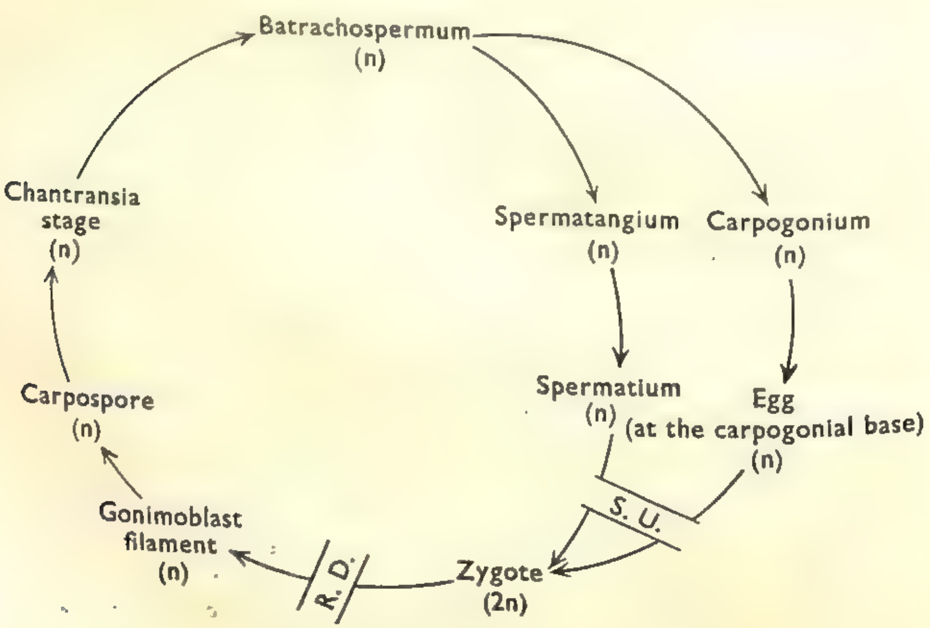


Fig. 107. Life cycle of *Batrachospermum*.

ORDER 6. CERAMIALES

Plants filamentous ; uniaxial ; tetraspores generally tetrahedral ; carpogonial branch 4-celled ; life cycle diplobiontic.

CERAMIUM

(Fam. CERAMIACEAE)

Ceramium occurs in abundance both in deep waters as well as between tidal levels, and is mainly marine. One or two species may be found in the rivers, particularly in the estuaries.

The common Indian species of *Ceramium* is *C. gracillimum.*

Vegetative body

The plants grow in tufts varying from 2 to 30 cm. in length and remain attached to rocky substrata by means of multicellular rhizoids, which form the holdfast. The thallus is irregularly, dichotomously branched with the apices of filaments incurved. In deep waters *Ceramium* appears red in colour, while in shallow tidal waters it exhibits a yellowish green or reddish brown colour. Each filament consists of a central siphon and can be differentiated into nodes and internodes. In some species, in mature condition, the nodes cannot

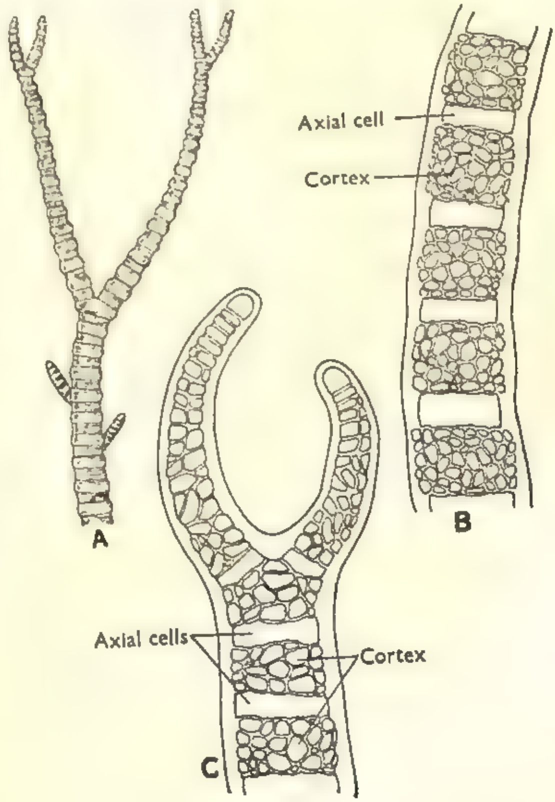


Fig. 108. *Ceramium.*
A, A portion of the plant body; B, A part of the mature thallus showing cortex and axial cell; C, The same showing dichotomous branching.

be clearly marked out owing to the presence of continuous cortical cells around them, while in others the nodal band of cortical cells becomes separated from one another by the axial cells. In some cases, spines may be developed from the primary cortical cells at the nodes. There is no apparent morphological differentiation between the sexual and asexual plants.

Reproduction

Ceramium reproduces both by sexual and asexual methods.

The plants are heterothallic. The **antheridia** or **spermatangia** are scattered over the entire surface of the thallus forming patches. They arise by the division of the cortical cells. Each

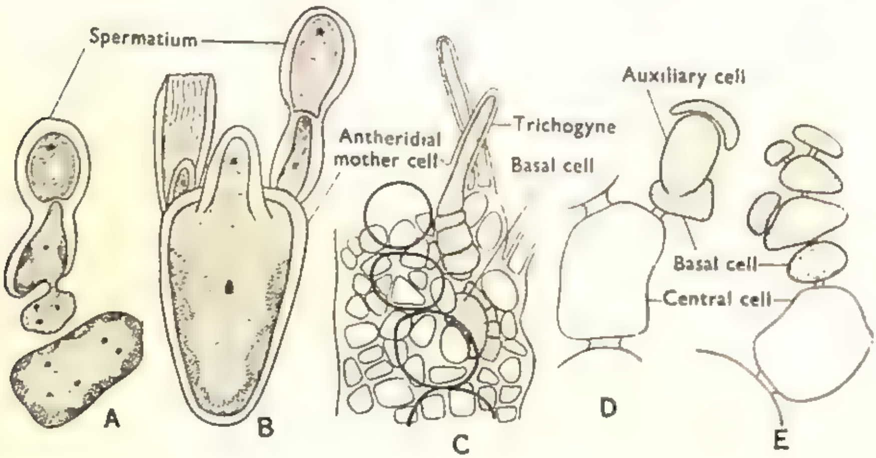


Fig. 109. *Ceramium*.
A—E, Different stages in the development of sex organs.

antheridium is a single-celled structure, which remains enclosed in a thick gelatinous wall and contains a single nucleus and a dense cytoplasm. By a rupture at the apex of the antheridium a solitary male gamete or **spermatium** is liberated. The spermatium is highly vacuolated and contains a solitary nucleus. The female sex organs (**carpogonia** or **procarps**) are produced terminally on short lateral branches. Each procarp branch is normally 4-celled and produced from the basal cell. The terminal cell of the carpogonium elongates at its tip forming a tubular **trichogyne.** Fertilization is effected by the union of the spermatial nucleus with the carpogonial nucleus. After fertilization, the

basal cell gives rise to a large **auxiliary cell,** on the side opposite to the procarp branch, into which passes the zygote nucleus. The auxiliary cell then by divisions gives rise to a number of **gonimoblast filaments.** From the tips of these filaments **carpospores** are produced, each of which on germination gives rise to the diploid **tetrasporic plant.** No well-developed cystocarp is produced, but the carpospores are partially protected by a number of short, lateral, upwardly projecting branches.

The asexual plant bears **tetrasporangia,** which arise in the cortical cells at the nodal regions. The nucleus of each tetraspore mother-cell divides meiotically giving rise to four haploid **tetraspores,** which may be arranged cruciately or tetrahedrally. Each tetraspore, on liberation, reaches a suitable substratum and forms a new gametophytic plant by division.

The life history cycle in *Ceramium*, thus, exhibits a triphasic alternation of generations.

In some species, some specialized spores, called **paraspores,** are formed on the tetrasporic (diploid) plants, but their germination has not been studied.

CALLITHAMNION

(Fam. CERAMIACEAE)

The species of *Callithamnion* are usually perennials inhabiting mud-covered rocky substrata near low water-mark levels in the tropical seas. Some are epiphytes with deeply penetrating rhizoids.

Vegetative body

The plant body is richly branched with an usual height of 2-5 cm. The branches are alternate and are arranged in definite spiral order (polystichous or distichous). Sometimes some of the lateral branches may exhibit pseudo-dichotomy. The central axis is composed of broad, thick-walled cells and generally the older parts remain enveloped by means of delicate, multicellular, corticating filaments. The cells are uninucleate or multinucleate, and generally possess ribbon-shaped chromatophores. The outer cells of the corticating filamentous envelope may also contain chromatophores. The plant remains anchored to the substratum

by means of multicellular rhizoidal filaments, coming out from the cortex as well as from the basal cells of the lower branches; these

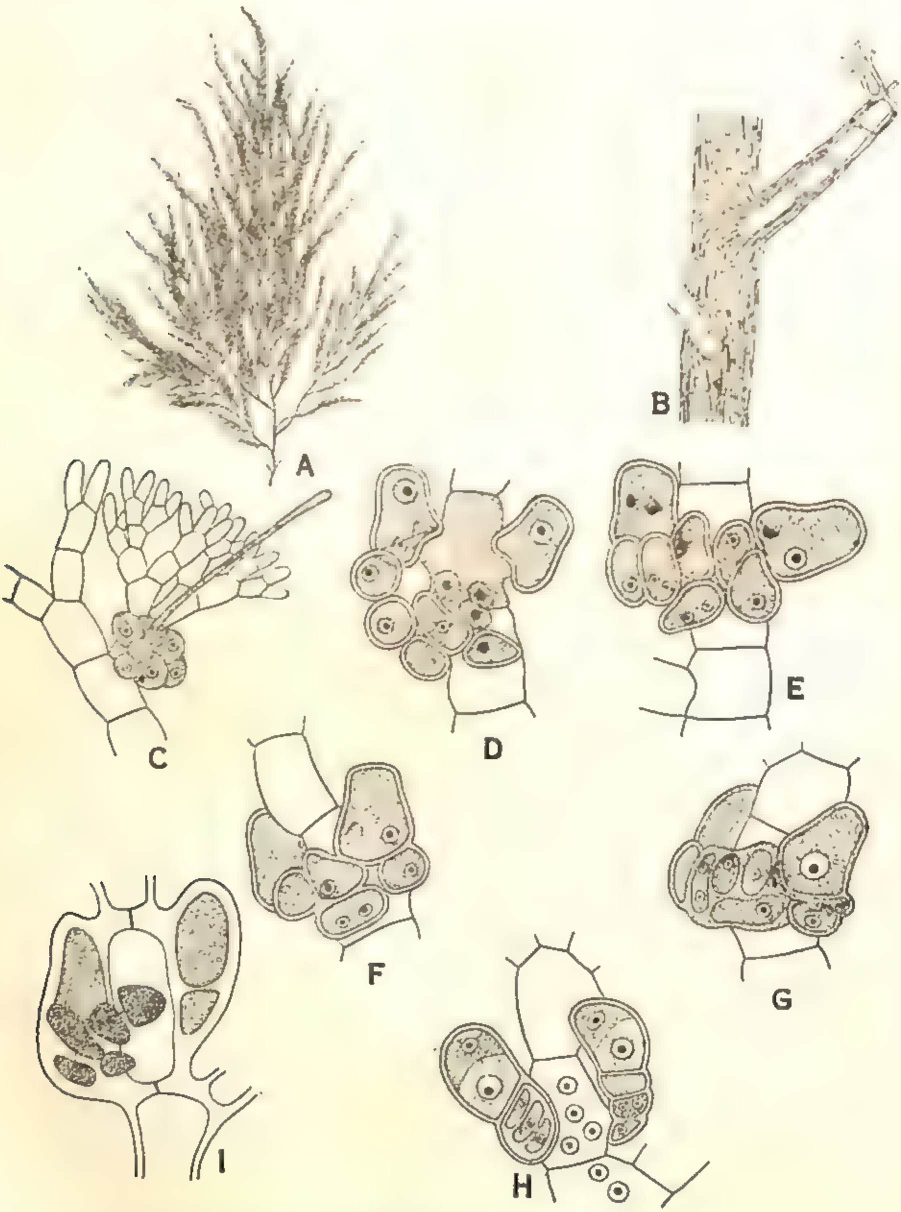


Fig. 110. *Callithamnion.*
A, The plant body; B, A portion of the same magnified to show cortication; C—I, Stages in the formation and development of sex organs.

filaments sometimes unite to form a definite disc-shaped holdfast.

Reproduction

Callithamnion reproduces both by sexual and asexual methods. The plant is heterothallic. The male plants are usually smaller than the female ones. The **antheridia** or **spermatangia** occur in spherical or cushion-like groups forming **sori** on the lateral branches. Each of these sori remains enclosed within a common gelatinous sheath and is composed of a mass of small-celled filaments, from whose tips the mother-cells appear; the mother-cells ultimately give rise to antheridia. The entire protoplasmic contents of an antheridium, on maturity, is liberated as a **spermatium.** The **procarp** generally has two mother-cells (**pericentrals**), only one of which bears the curved, 4-celled **carpogonial branch.** The position of the **carpogonium** is approximately midway between the two mother-cells and it consists of a dilated basal region containing the egg nucleus inside, and a distally tapering **trichogyne.** A liberated spermatium, while floating on water, lodges against the trichogyne. A dissolution takes place at the point of contact and the spermatial nucleus passes down through the opening and unites with the egg nucleus. After fertilization, each of the two mother-cells, lying on the two sides of the carpogonium, cuts off an **auxiliary cell.** The carpogonium, at this stage, becomes broader and divides longitudinally forming two cells. Each of these cells, in its turn, cuts off a small **connecting cell,** which joins up with the minute protuberance developed from the adjacent auxiliary cell. The haploid nucleus of the auxiliary cell sinks to the bottom along with one of the two diploid nuclei, while the other diploid nucleus migrates to the apical region of the auxiliary cell. The basal region of the auxiliary cell, containing degenerating auxiliary as well as the diploid nuclei, is cut off from the apical portion by means of a septum. The apical region of the auxiliary cell then produces the **gonimoblast filaments** which bear **carposporangia.** The naked, usually spherical masses of carposporangia remain enclosed in a common gelatinous sheath. Each carposporangium liberates a single **carpospore,** which on germination gives rise to a diploid plant, called the **tetrasporophyte.** No definite cystocarp is formed.

The tetrasporophyte bears **tetrasporangia** developed from the fertile pericentral cells, only one pericentral cell of a transverse tier giving rise to a sporangium. The single nucleus of the tetrasporangium undergoes meiotic divisions and four

tetrahedrally arranged **tetraspores** are ultimately formed. On liberation the tetraspores develop into the gametophytes.

There is, thus present in the life cycle of *Callithamnion*, a definite triphasic type of alternation of generations.

In some species, there occur **polysporangia** in the position of the tetrasporangia which develop **polyspores** within. It is believed that the polyspores are mere derivatives of the tetraspores.

POLYSIPHONIA

(Fam. RHODOMELACEAE)

Polysiphonia, the most thoroughly studied red alga, is well known and the details of its life history illustrate certain principal features of Rhodophyceae in general. It chiefly occurs in shallow water along the coasts of the Atlantic and Pacific oceans; some species may also grow as epiphytes on certain members of the family Fucaceae.

The common Indian species of *Polysiphonia* is *P. angustissimum*.

Vegetative body

The thalli in general are small, being a few to several centimetres in length. Each thallus is made up of several united filaments or siphons, from which the name '*Polysiphonia*' is derived. It bears at its basal end an elongated, unseptate rhizoid, whose apical portion expands to form an irregularly lobed holdfast. Secondary rhizoids may also develop from the lower portion of the thallus for additional anchorage of the plant. The thallus, as it grows lengthwise, produces along its length in a spiral succession dichotomously-branched, gradually tapering multicellular filaments, the **trichoblasts,** made up of a single row of cells (uniseriate). In some species, the older portion of the '*polysiphonous*' thallus may become ensheathed (corticated) by the formation of a peripheral layer of small cells. The characteristic protoplasmic connections are evident between the vegetative cells of the thallus. The uninucleate protoplast of a trichoblast cell is usually colourless, or it may contain a faintly coloured chromatophore.

Reproduction

Polysiphonia reproduces both by sexual and asexual methods.

Most species of *Polysiphonia* are heterothallic. The male sex organs, the **spermatangia,** are produced from superficial **sper-**

Fig. 111. *Polysiphonia*.
A portion of the thallus showing the general habit.

matangial mother-cells in very dense clusters upon the branches of the fertile trichoblasts, situated near the growing

apex of the male thallus. A spermatangial mother-cell produces 2-4 spermatangia, each of which is a simple, single cell structure producing a **spermatium.** At maturity, the wall of the spermatangium ruptures and the spermatium escapes as a single-walled cell, leaving the empty wall of the spermatangium attached to the filament. It floats in water and is finally carried to the carpogonium.

The female sex organ, the **carpogonium,** is produced upon a greatly reduced fertile trichoblast of a female gametophyte. The branch bearing the carpogonium is called the **carpogonial branch,** which is a curved, 4-celled filament, whose terminal cell is metamorphozed into a carpogonium. One of the adjacent cells is known as the **auxiliary cell.** The carpogonium consists of an enlarged, uninucleate, basal portion and an elongated upper portion, called the **trichogyne,** with its ephemeral nucleus.

At the time of fertilization, the spermatium attaches itself to the trichogyne, the intervening walls dissolve, and its nucleus migrates into the trichogyne and then into the carpogonial base, where it fuses with the nucleus of the carpogonium. Meanwhile, the auxiliary cell makes a tubular connection with the base of the carpogonium. With the fusion the diploid number is established in the resulting zygote nucleus. After fertilization, the zygote nucleus migrates into the auxiliary cell and divides mitotically several times so that there are several diploid nuclei mixed with several haploid nuclei owing to the fusion of the adjacent sterile cells (**supporting cells**). These are embedded in the cytoplasm with sufficient amount of reserve materials enclosed within the common wall of the carpogonial base. From this structure numerous short multicellular filaments (**gonimoblast filaments**) begin to develop into which the diploid nuclei migrate. At the distal end of each filament a spore, called the **carpospore,** is formed within an unicellular **carposporangium.** The carpospore evidently contains a nucleus with the double number of chromosomes. Along with the development of the carpospores, certain cells of the haploid filaments also grow up and cover the mass of filaments bearing the carpospores. This resulting enveloping structure is haploid and urn-shaped containing within it the diploid carpospores, and the whole structure is called the **cystocarp.** When the carpospores attain maturity, they are liberated from the cystocarp and each on germination produces the asexual or sporophytic plant

(**tetrasporic plant** or **tetrasporophyte**). The plant, thus produced from the diploid carpospore is, therefore, a diploid structure.

The tetrasporic plants are strictly asexual in nature and produce sporangia on short stalk-cells, derived from the central region of the axis of the plant in course of developmeut. Each sporangium is a **tetrasporangium,** since its nucleus during development undergoes reduction division forming four haploid nuclei, around which a group of four spores, called **tetraspores,** is formed during the maturation period. The tetraspores, at

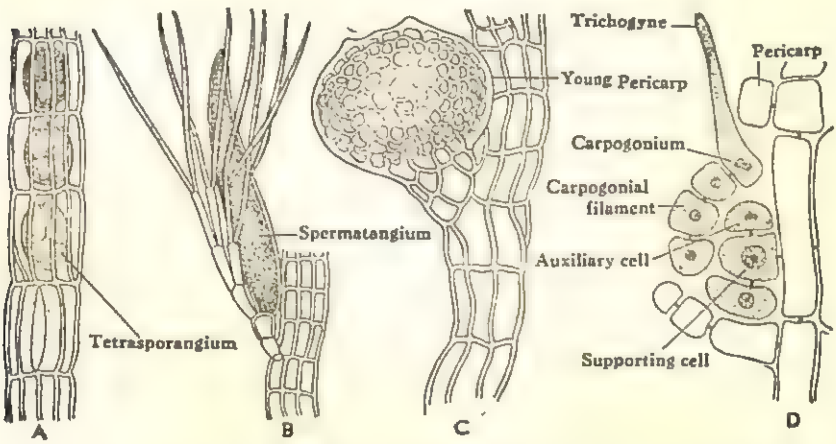


Fig. 1·12. *Polysiphonia.*
A, Small portion of tetrasporangial branchlet showing tetrasporangia; B, Small portion of branchlet showing spermatangium and branched hairs; C, Small portion of branch with young pericarp; D, A carpogonial branch after fertilization and formation of auxiliary cell.

maturity, are liberated by rupture of the sporangial wall. Half of the tetraspores on germination produces the male gametophytes, the other half, the female gametophytes.

Thus, in the life history of *Polysiphonia* there are plants of three kinds: (1) **male plant** bearing spermatangia, (2) **female plant** bearing carpogonia and ultimately forming cystocarp as a result of fertilization, and (3) **tetrasporic plant** developed from carpospore and producing spores in groups of four, called tetraspores. Half of the tetraspores on germination produce the male plants and the other half, the female plants. Thus, in the life cycle, the male and the female plants represent the sexual or gametophytic genera-

tion, while the tetrasporic plant, which never produces gametes but always produces tetraspores, represents the asexual or sporophytic generation. These sexual and asexual plants not only differ in their functions, but they reproduce each other in succession showing an alternation of generations.

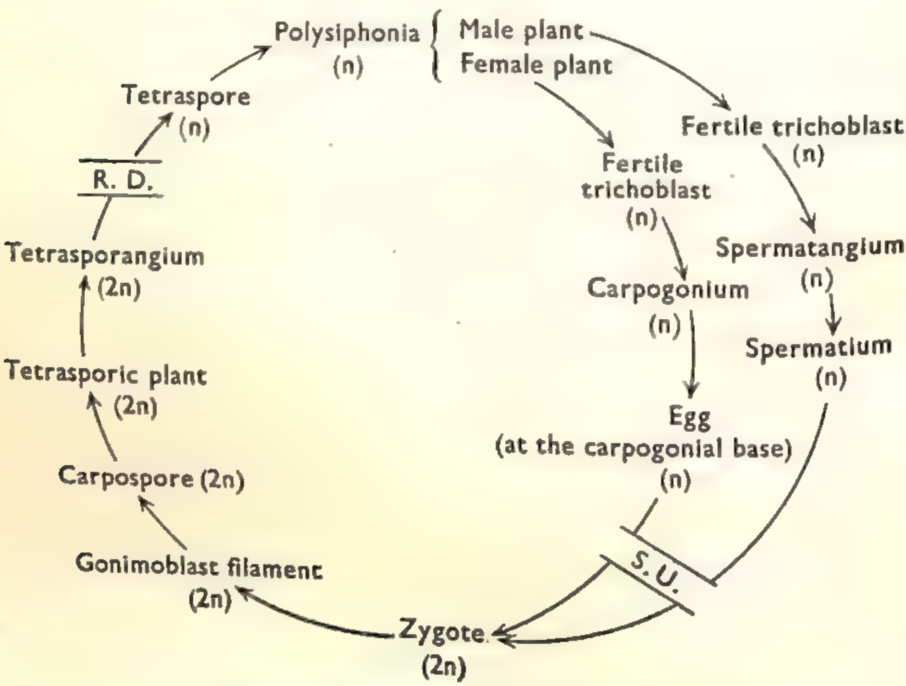


Fig. 113. Life cycle of *Polysiphonia*.

CLASS XI. MYXOPHYCEAE (CYANOPHYCEAE)

Salient features

The chief characteristics of Myxophyceae are: (1) a primitive and simple type of cell structure, (2) the presence of a blue pigment called **c-phycocyanin** and a red pigment (**c-phycoerythrin**) in addition to the usual photosynthetic pigments (chlorophyll *a*, carotenes and xanthophylls) and these are not localized in the chromatophores but are distributed in the peripheral portion of the protoplast, known as **chromoplasm,** and (3) the presence of a primitive type of nucleus, called **central body,** which lacks a nucleolus and a nuclear membrane. Other prominent features which are not restricted to them alone are: (1) the presence of an outer gelatinous cell wall surrounding the protoplast, (2) production of photosynthetic reserves, mainly in the form of glycogen but not starch, (3) total absence of sexual reproduction by gametic union, and (4) the lack of formation of any flagellate asexual reproductive unit.

General characters

This group of blue-green algae consists of a small assemblage of primitive thallophytic plants, not apparently closely related to other subdivisions of algae. They are inhabitants of damp terrestrial places or are entirely aquatic in nature. Among aquatic forms a great majority are freshwater species as free-floating organisms (**plankton**). Some species are marine and may occur as epiphytes on other marine algae, or are found within their tissues as endophytes.

The vegetative body may remain strictly unicellular. This is due to immediate separation of daughter cells following cell divisions. In great majority of species, however, the daughter cells following cell divisions remain united with one another forming a multicellular filamentous or non-filamentous thallus. The non-filamentous colonies arise due to the union of gelatinous walls surrounding individual cells. This union may be so complete that the existence of individual gelatinous envelopes disappear completely (e.g., *Microcystis*), or it may be incomplete, so that a more or less recognizable sheath is evident around each cell (e.g., *Gleocapsa, Chroococcus*). The form of a non-filamentous colony depends upon the planes in which its cells divide. Thus, division in two planes results in a layer of cells which may be either a flat plate (e.g., *Merismopedia*) or a hollow sphere (e.g., *Coelosparium*). If the divisions are regular and in three planes, a cubical colony results (e.g., *Eucapsis*), or the arrangement of cells in the colony may be quite irregular (e.g., *Microcystis*). If the divisions take place repeatedly in a single plane, a filamentous colony is formed (e.g., *Oscillatoria, Nostoc, Anabaena, Rivularia, Gleotrichia*).

In a filamentous colony, the cells either remain united together by the common walls of the adjacent cells or a single row of cells remains enclosed within a gelatinous sheath. A single row of cells is termed a **trichome.** A trichome with its surrounding sheath is called a **filament.** Within a filament there may be a single (e.g., *Nostoc, Porphyrosiphon*) or several trichomes (e.g., *Microcoleus*). The trichome may either be of uniform diameter (e.g., *Porphyrosiphon*), or it is gradually narrowed towards the distal end (e.g., *Rivularia, Gleotrichia*). The trichomes are generally unbranched, but in a few cases they may be branched (e.g., *Nostocopsis*).

In unicellular forms, the cell wall surrounding each protoplast consists of two concentric portions: (a) an inner thin and firm

layer, chiefly made up of cellulose, and (b) an outer gelatinous portion, often called the **sheath.** This sheath may be thick or thin, hyaline or coloured, and may often be stratified in appearance. On the other hand, in filamentous colonies this gelatinous layer is restricted only to the free and outer faces of the cell.

The protoplast of Myxophyceae presents an extremely interesting but difficult problem. All investigators recognize that the protoplast consists of an outer pigmented portion, called the **chromoplasm,** which surrounds a clear central portion, the so-called **central body.** These parts have been variously interpreted from time to time. The majority of investigators consider the central body as the nucleus and the outer portion as the cytoplasm containing pigments in the form of minute granules, the cell lacking any definite chloroplast. Recent investigations show that the central body may be regarded as the primitive or 'incipient' nucleus, which consists of a network of colourless material in the meshes of which are embedded granules of chromatin. This primitive type of nucleus illustrates a step in the process by which nuclei of higher plants have been evolved. The peripheral portion has been recognized to be the cytoplasm corresponding to the cytoplasm of higher plants.

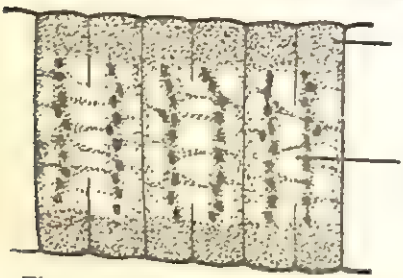


Fig. 114. Structure and divisions of the cells in Myxophyceae.

The chromoplasm of a myxophycean cell may contain a green pigment (**chlorophyll a**), yellowish pigments, *carotenes* (**b-carotene** and **flavicin**), and xanthophylls (**myxoxanthophyll**), a blue pigment (**c-phycocyanin**) and a red pigment (**c-phycoerythrin**). Of these, chlorophyll *a*, b-carotene and c-phycocyanin predominate. All these pigments are neither always present in the protoplast nor are present in equal amounts.

Reserve food, mostly in the form of granules, is present in the pigmented portion of the protoplast. Some think that these granules are glycogen, while according to others, these are glyco-proteins. Besides these, there are also true protein granules and minute droplets of oil, but no starch.

Many freshwater planktonic species of Myxophyceae show the

presence of **pseudo-vacuoles** in their protoplasts. These appear as black bodies under low magnification of a microscope and are distributed throughout the protoplasts. Under high magnification they appear somewhat reddish in colour, which is probably a refraction phenomenon. At first these pseudo-vacuoles were thought to be gas-filled vacuoles, since by pressure or in a partial vacuum they disappear and gas bubbles appear near the surface of the cell. Others believe them to be cavities filled with a viscous substance. They probably give greater buoyancy to planktonic species and act as light-screens against intense illumination.

Some filamentous species of Myxophyceae have the ability to move spontaneously. The locomotion may be due to the forward or backward gliding of the filament, spiral progression or retrogression, or a slow waving of the terminal portion of the filament. This is remarkably affected by various external factors, such as temperature, light, etc. Increased illumination and gradual rise of temperature from 0°-30°C accelerate movement.

The members of the Myxophyceae are very successful in terrestrial and subaerial habitats, and can tolerate a wide range of external conditions. The presence of a mucilagenous sheath around the cell or the trichome increases the water-absorbing and water-retaining capacity of the plant. The cells do not readily plasmolyze due to the absence of large vacuoles and elasticity of the cell walls. This, helps them to tide over prolonged drought with little change. The power of adjustment to lights of different intensities and due to colour variation many species are able to utilize the different qualities (colour) of available light, and thus can grow in diverse habitats. The so-called pseudo-vacuoles or gas-vacuoles give them a greater buoyancy for planktonic existence or serve as light-screens allowing only optimum light.

Reproduction

The methods of reproduction are extremely simple and are entirely asexual in nature, there being no production of flagellate gametes. Formation of thick-walled **resting spores** or **akinetes** or **heterocysts** also help the plants to tide over unfavourable conditions. Asexual reproduction may take place by the following methods.

Cell division. In unicellular types, multiplication takes place by cell division and the two daughter cells, thus formed, remain

united by a common gelatinous sheath. Repeated cell divisions, in this way, give rise to a non-filamentous colony. But in case of multicellular forms, this process of cell division becomes a method of growth and not a means of multiplication.

Fragmentation. In filamentous forms, thalli capable of indefinite growth, usually break up under certain conditions into smaller portions, consisting of 2, 3 or more cells called **hormogones.** Each hormogone, by cell division, gives rise to a new filamentous colony and possesses great capacity for locomotion. This breaking up of the filament is either due to animal beings, or death of certain cells of the filament, or weaker union between certain cells of the filament.

Spore formation. In most filamentous forms, certain vegetative cells of the filament form some kind of resting cells, called **akinetes.** During the formation of an akinete, a vegetative cell enlarges, accumulates reserve food within it and the entire protoplast becomes invested by the appreciably thickened original cell wall forming the spore coat, which is often differentiated into an outer **exospore** and an inner **endospore.** The spores remain either singly or in groups and may either occur anywhere in the filament or have a fixed position (next to the heterocyst). They are resistive to unfavourable external conditions, can tide over unfavourable periods and germinate during the rainy season giving rise to new individuals.

In some marine forms, the protoplast of certain vegetative cells may divide to form a number of small, spherical or angular spores, called **endospores,** filling the original cell cavity.

Heterocyst formation. All filamentous Myxophyceae, excepting the members of the Family Oscillatoriaceae, form spore-like bodies which differ structurally from ordinary vegetative cells and spores. They occur singly or in pairs, and are either terminal or intercalary in position. During development, a very young vegetative cell expands, its protoplasm becomes transparent, homogeneous and viscous, and a wall, internal to the original cell wall, is secreted round the protoplast. If the heterocyst occupies the terminal portion of the filament, there is a pore on its wall through which cytoplasmic connection between it and its adjacent vegetative cell can be observed. On the other hand, if it be intercalary, there are two such pores, and these pores are closed at maturity by button-like thickenings, called **polar nodules.** Heterocysts

are generally functionless, but they may germinate in exceptional cases.

Classification

The Myxophyceae is divided into *five* Orders (Fritsch, 1942) as follows :

(a) *Hormogones absent*

Order 1. Chroococcales :—Thallus unicellular or colonial; reproduction by cell division and by the formation of endospores; mostly freshwater, some lithophytes. Examples—*Chroococcus, Gleocapsa, Aphanotheca, Aphanocapsa*, etc.

***Order 2. Chamaesiphonales**:—Thallus unicellular or colonial; reproduction by endospores or exospores; epiphytes or lithophytes, marine or freshwater. Examples—*Chamaesiphon, Darmocarpa*, etc.

***Order 3. Pleurocapsales**:—Thallus filamentous, heterotrichous and without heterocysts; reproduction by the formation of endospores; generally marine lithophytes, also in lakes and in rapid streams while a few are marine epiphytes. Examples—*Pleurocapsa, Radaisia*, etc.

(b) *Hormogones present*

Order 4. Nostocales:—Thallus filamentous, non-heterotrichous, commonly with heterocysts and often showing false (rarely true) branching; reproduction by hormogones, heterocysts and akinetes; large majority occur in freshwater as hydrophytes or lithophytes. Examples—*Nostoc, Oscillatoria, Lyngbia, Anabaena, Rivularia, Gleotrichia, Scytonema*, etc.

***Order 5. Stigonemales**:—Thallus filamentous, heterotrichous with true branching and mostly with heterocysts; reproduction by hormogones and heterocysts but rarely by akinetes; mostly as lithophytes or freshwater hydrophytes. Examples—*Stigonema, Nostocopsis*, etc.

ORDER 1. CHROOCOCCALES

Thallus unicellular or colonial ; reproduction by cell division and by the formation of endospores ; mostly freshwater, some lithophytes.

*Not treated in this book.

Reproduction

Nostoc reproduces asexually either by fragmentation, or by the formation of akinetes. A filament seems to break off easily, next to the heterocyst, forming short filaments called **hormogones.**

ANABAENA

(Fam. Nostocaceae)

Anabaena occurs in nature, either singly or in colonies, forming free-floating floccose masses. Sometimes it forms a delicate mucous layer on the surface of the soil. It is primarily an aquatic alga and is found in abundance in semi-permanent pools. Many species occur as planktons in lakes and ponds forming water-blooms. *Anabaena azollae* is found within the leaves of *Azolla,* and *A. cycadeae* occurs as an intercellular parasite in the cortical tissues of the coralloid roots of *Cycas.*

The common Indian species of *Anabaena* are *A. ballyganji*, *A. circinalis*, *A. ambigua*, *A. orientalis*, *A. mollis*, *A. variabilis*, *A. fertilissima*, etc.

Vegetative body

The thallus is an unbranched, straight, circinate or irregularly contorted filament of uniform thickness throughout its entire length or slightly narrowed at the ends. Each filament consists of a trichome which is enveloped by a watery, hyaline sheath of variable thickness. The cells of the filament are usually spherical or barrel-shaped and contain protoplasts, which are either homogeneous or granulose and filled with numerous pseudo-vacuoles. The colour of the filament is variable, but usually it is grey or blue-green. There are always several intercalary **heterocysts,** which occur usually singly and are approximately of the same shape as the vegetative cells.

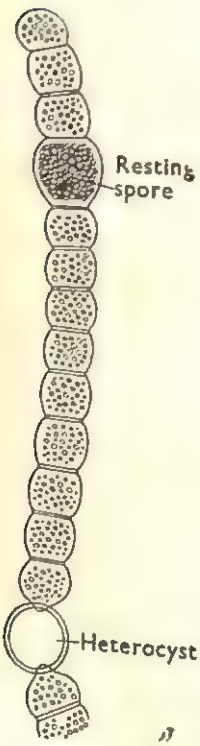


Fig. 118. *Anabaena.*

Reproduction

Anabaena, like *Nostoc*, reproduces asexually, either by the formation of hormogones or by means of akinetes. These

akinetes develop singly or in chains, either next to the heterocysts or remote from them or in both positions. They are larger than the vegetative cells and are more or less cylindrical in shape with rounded ends.

Both *Anabaena* and *Nostoc* resemble each other so closely that it becomes very difficult to distinguish between the two. *Anabaena* never forms colonies of definite form in which the trichomes are usually not contorted. Besides the sheath around the trichome is extremely hyaline and gelatinous. *Nostoc*, on the other hand, possesses a colony with a firm envelope, and within the colony the trichomes are very much contorted.

RIVULARIA

(Fam. Rivulariaceae)

Rivularia usually grows on submerged substrata, such as stones, woodworks and stems of water plants. Occasionally it is found on rocky cliffs. It forms hemispherical thalli of united filaments of exceedingly firm consistency and often heavily incrustated with lime.

The common Indian species of *Rivularia* are *R. globiceps*, *R. lens*, *R. natans*, etc.

Vegetative body

Each filament is whip-like and consists of a single trichome, which is gradually attenuated from the base to the apex, and surrounded by a distinct sheath. There is always a **heterocyst** at the base of each trichome. The sheath, either homogeneous or stratified, is usually distinct towards the lower portion of the trichome. The sheaths of several such filaments become partially or wholly fused forming hemispherical, globose or expanded masses of macroscopic size. Within such a mass, the filaments are somewhat radiately arranged, and this is due to repeated false branchings towards the basal portion of the thallus. But these branches are so much

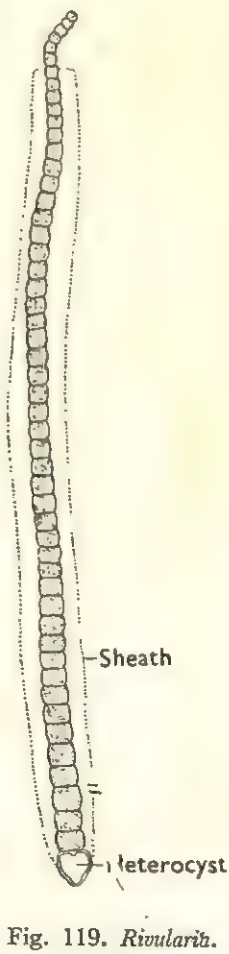


Fig. 119. *Rivularia*.

displaced that it becomes difficult for observation in a mature thallus.

Reproduction

Reproduction takes place by the formation of **hormogones** which are normally developed towards the distal end of each filament. Akinetes are not found in this alga.

GLEOTRICHIA

(Fam. RIVULARIACEAE)

Species of *Gleotrichia* are always aquatic. They form spherical or hemi-spherical masses, which are either free-floating or attached to some submerged substrata throughout their entire surface. In some species, the thalli at first remain attached to the substratum but eventually become free-floating.

The common Indian species of *Gleotrichia* are *G. atra*, *G. natans*, *G. raciborskii*, *G. pisum*, etc.

Fig. 120. *Gleotrichia.*

Vegetative body

The filament of *Gleotrichia* is more or less similar in structure with that of *Rivularia*, having trichomes gradually attenuated from base to apex with enclosing gelatinous sheaths, which are wholly confluent with one another forming globose or hemi-spherical masses. There occurs the same basal **heterocyst,** but in addition intercalary ones are also found. The filaments always possess **akinetes,** either singly, next to heterocysts, or in short series separated from one another by two or three vegetative cells.

Reproduction

Reproduction takes place by formation of **hormogones** formed towards the distal ends of the filaments, and by means of akinetes.

SCYTONEMA

(Fam. SCYTONEMACEAE)

Scytonema usually occurs in sub-aerial habitats, such as damp soil, dripping faces of rocks, etc., forming felty masses of interwoven filaments, but may also occur in hot springs.

The common Indian species of *Scytonema* are *S. amplum*, *S. aureum*, *S. javanicum*, *S. caldarium*, *S. tomentosum*, *S. varium*, *S. simplex*, *S. pascheri*, etc.

Vegetative body

The trichomes of *Scytonema* consists of more or less cylindrical cells and are usually of uniform diameter throughout. Sometimes slight or marked constrictions appear at the transverse walls. The trichomes are surrounded by sheaths of extremely fine texture and may be hyaline or yellowish or brownish in colour. The sheath may be homogeneous throughout or stratified, and the stratifications are either parallel or oblique. The filaments show characteristic false branching. The trichome, during the process of multiplication, becomes fragmented, either due to disintegration of the intercalary cells or due to formation of separating disks or heterocysts. These fragments are immobile and begin to grow within the original sheath. The branching results due to interruption of such newly formed trichomes at certain points. As a result, portions of one or both the trichomes perforate the firm sheath and grow out as laterals, which secrete a distinct sheath of their own. These false branches usually appear in pairs and occupy approximately the middle portion between two heterocysts.

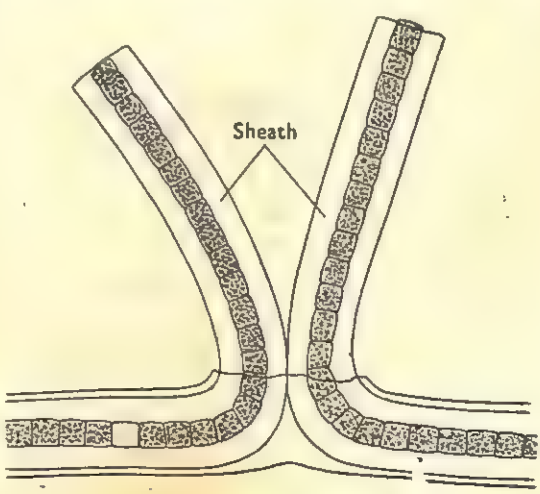


Fig. 121. *Scytonema*.

The **heterocysts**, intercalary in origin, occur singly or in series of

twos or threes. They are more or less of the same size as the vegetative cells.

Reproduction

Reproduction by means of **hormogones** is usually the only method of multiplication. Akinetes are rarely formed in this alga.

Origin and evolution of sex in algae

The starting point in the origin of sexuality is denoted by the formation of gametes. The different types of sexual reproduction in algae range from isogamy to oogamy, the culminating point.

Ulothrix, in which modes of formation of gametes and zoospores are identical, has often been taken to illustrate the possibility of the origin of gametes from zoospores, consequently, the origin of sex. Two types of zoospores, large and small, are produced in *Ulothrix* depending on the number of successive nuclear divisions, and the smaller zoospores are morphologically alike with gametes and also in the method of production. The difference between the gametes and the zoospores depends mainly, therefore, in the number of nuclear divisions occurring during their development. When the number of divisions is less, the zoospores are formed, but when it is long continued, gametes develop. It has been suggested that possibly due to accidental fusion of the small zoospores in pairs sexual reproduction has originated. The larger zoospores on germination can only give rise to strong individuals, but the smaller ones on germination can produce only weaklings. But, if these smaller zoospores combine in pairs, zygotes are produced, and the resources of the two fusing cells are brought together forming a new identity full of increased vitality and vigour. This act of union of two naked protoplasts is a sexual act, and the two fusing cells are, therefore, regarded as sexual cells or gametes. The sexual reprodutction originates when zoospores behave as gametes. It is believed that sexual reproduction in plants takes place in response to unfavourable environmental conditions for vegetative activity. When the conditions are most favourable, the plant usually reproduces vegetatively. When these conditions are on the decline, the plant reproduces sexually and the gametes are produced. These gametes, by fusing in pairs, produce zygotes, which usually pass into a state of dormancy or resting period, and in this condition the plant perennates. Thus, the formation of zygote is

more in response to unfavourable growing conditions for the protection against extermination of the individual than a method for the multiplication of the plant.

The origin of sex in algae is associated with the gradual differentiation of sex. By differentiation of sex is meant the morphological differentiation, *i.e.*, difference in appearance, which involves in the difference in size and activity of the motile organs associated with it. This differentiation of sex leads to such differentiation of gametes that they can be easily recognized as male and female ones. Morphological similarity of pairing gametes is called **isogamy,** while morphological dissimilarity of the pairing gametes is called **heterogamy.** In isogamous plants the terms 'male' and 'female' are not used, but in heterogamous ones they are commonly applied. The type of isogametes which gradually gives rise to heterogametes is clearly of the active swimming zoospore type, the two copulating gametes being similar in size and activity. Beginning with this type of gamete, a series of algae can be arranged in which there are increasing differences, step by step, in the pairing gametes and culminating with gametes, morphologically so different in appearance that they can be easily recognized as male and female, and do not suggest identical origin. It is the gradual appearance of differences that makes the two sexes recognizable and not due to gradual differentiation of maleness and femaleness. In the series of differentiation of sex among algae beginning with isogamy there are types in which one of the pairing flagellate gametes becomes recognizably larger than the other (**anisogamy**) to the types in which this relative difference in size gradually increases until finally one of the pairing gametes becomes non-flagellate, non-motile, passive and many times larger than that of its small, active and flagellate mate (**oogamy**).

The following cases may be chosen to illustrate the gradual differentiation of sex among algae :

Chlamydomonas, *Ulothrix*, *Ectocarpus*, etc., illustrate isogamy, in which the pairing gametes are zoospore-like bodies which are flagellate and motile. *Spirogyra* is also isogamous, and the fusing gametes are non-flagellate but are ordinary protoplasts of vegetative cells. Of the two fusing gametes, one remains passive and the other moves through the conjugation tube and fuses with it. This difference in motility is a feature of sperm and egg, therefore, the two pairing protoplasts of *Spirogyra* may be regarded as male and

female, although they do not differ in size. *Zygnema*, a relative of *Spirogyra*, has both of its fusing gametes motile at the time of union. Therefore, the advance to the condition of *Spirogyra* is the entire loss of motility of one gamete and its retention by the other.

The next step in the evolution of sex is anisogamy, which may be illustrated by forms like some species of *Chlamydomonas*, *Pandorina*, *Caulerpa*, etc., where the fusing gametes, differing only in size, are both flagellate. In *Pandorina* both the gametes are motile, but the larger one may be more sluggish than its mate. In a few species of *Chlamydomonas* and in *Eudorina*, a relative of *Pandorina* and *Volvox*, one may be motile, the other immobile, and hence, they show a very close approach to oogamy in that the larger gametes are not free-swimming and in that the gametes are dissimilar in size and shape.

The maximum differentiation of sex is found among oogamous forms like *Volvox*, *Oedogonium*, *Vaucheria*, *Chara*, *Fucus*, etc., in which the gametes are not only differentiated into male and female by their differences in size, but also due to the fact that the larger female gamete becomes a completely passive cell so far as motility is concerned, due to the final disappearance of its swimming appendages (flagella). On the other hand, the male gamete becomes less bulky than its mate and develops swimming mechanism as a secondary feature.

The mode of sexual reproduction in Rhodophyceae, though oogamous, is of a highly specialized nature and illustrates further essential feature of the gametes. In this group distinct male and female organs are present, but the sperms resembling ordinary protoplasts are not even detached from the cell walls. In some cases, they are discharged but without any swimming appendages, and sometimes they are not discharged. Within the female sex organ no egg is recognizable as different from the ordinary protoplast. It does not separate from the wall of the sex organ and rounds off, so that it is not a typical egg. It is simply the protoplast functioning as the female gamete, because the sperm or its nucleus fuses with it. Thus, in this group, the sexuality is of a distinctive type, there being no eggs and sperms in the ordinary sense, their role being played by two protoplasts not different in appearance from vegetative protoplasts.

Economic importance of Algae

The economic importance of the algae lies in the fact that they are

either beneficial or harmful in their activities. Some of them are also important from the medicinal standpoint of view, as they are very rich in substances like iodine, carbohydrates, and vitamins A, C, D and E. A brief account of the economic importance of the different groups of algae is given below.

The blue-green algae form an important link in the so-called 'food chain'. These algae form the food for the various fishes and aquatic animals, which are in their turn taken up by human beings. Some members of this group occur very densely in water producing the 'water bloom'. Such a water may prove to be poisonous for the cattle. Further, they impart a fishy taste and a stinky odour to the water in which they occur. Some species of soil-inhabiting blue-green algae add fertility to the soils.

The green algae also constitute food for freshwater as well as marine animals. Some members, like *Ulva* are even taken by man. Members of the green algae play a vital role in the purification of water in which they grow. They utilize the carbon dioxide released by the various aquatic animals during their respiration for the purpose of photosynthesis, while they themselves give off oxygen in the process, which is taken in by these animals. Some marine green algae help to a great extent in the formation of reefs in the oceans.

Perhaps the only drawback of the golden brown algae is that they contaminate water supplies. In comparison to this, the beneficial uses of the diatomaceous earth is immensely manifold (vide p. 150).

The brown algae, like *Fucus*, *Laminaria*, *Sargassum*, and certain other kelps, are very good sources of iodine, while genera like *Pelagophycus*, *Macrocystis*, *Nereocystis*, and some others furnish us with potash. *Sargassum* is also a good cattle food. Some of the brown algae are taken as food by man, particularly by the Chinese, and by the Japanese. The Americans are also fond of "Seatron", which is a preparation made from the bladders and stalks of *Nereocystis*.

A large number of red algae along with other groups of algae form the source of food for the fishes, and a few, like *Rhodymenia*, are taken by the cattle. *Rhodymenia* is also eaten by man as well. *Porphyra*, *Chondrus crispus*, etc., are used in the preparation of soups, or desserts and puddings. *Gelidium* is the source of agar, which has got diverse uses. Agar is used for the preparation of culture media for fungi and bacteria, as well as a sizing material in the textile

industry, as a laxative, and as a solidifying agent in the preparation of desserts. A large number of red algae yield gelatin or jellies, which are used for different commercial purposes, like the preparations of shampoos, cosmetics, hair dressings, shaving creams and other articles of toilet, shoe polishes, lubricating jellies, ice-creams and desserts. The red algae also play a much more important role in the formation of the so-called "coral reefs" in the oceans than do the coral animals themselves.

CHAPTER II

THALLOPHYTA (*Contd.*)—FUNGI

This great group of thallophytes is readily distinguished from other groups by the total lack of the photosynthetic pigment, chlorophyll, resulting in the disability of manufacturing their own food. Hence, they are compelled to live either as parasites, or as saprophytes. But, sometimes they live in close association with algae, as in the case of lichens; such a mode of life is known as **symbiosis,** in which the associates derive mutual benefit from each other. They also live in close association with the roots of certain higher plants, particularly forest trees. This combination of the fungus and the host is known as **mycorrhiza.** This symbiotic physiological relationship does not seem to be distinctly harmful to the tree, yet it is often thought to be a mild form of parasitism. The habitats of fungi are extremely diverse. They not only occur as parasites forming **haustoria** within the host cells, and saprophytes, but are often found as epiphytes and may even be subterranean.

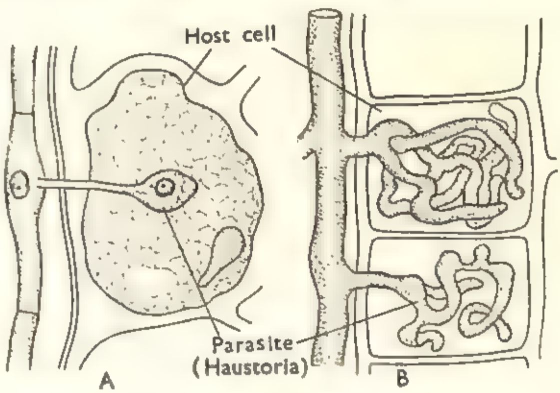


Fig. 122. Different types of haustoria. A, Formation of appresorium within the host cell; B, Formation of finger-like processes within the host cell.

Most fungi have a life history which consists of two phases: (a) **vegetative phase,** in which the fungus grows through the host or substratum and constructs its vegetative body, and (b) **reproductive phase,** in which the fungus produces spores or other reproductive structures by means of which it perpetuates itself.

The vegetative body, with the exception of the unicellular forms, consists of a more or less extensive, much-branched, filamentous, colourless or coloured structure, called the **mycelium,** in which a

single filamentous branch is called a **hypha.** This mycelium originates as a result of germination of a **spore,** which, in the simplest case, is unicellular and uninucleate and may or may not be motile. A spore germinates, by pushing out from any point or from a thin place (**germ pore**) on its wall, in a tube-like or a filament-like process, called the **germ tube.** Rapid elongation and branching follow and a mycelium is formed, the growth of the hypha being restricted at the tip.

The mycelium may be septate or aseptate. When aseptate, the protoplasm is continuous throughout and contains numerous minute nuclei and vacuoles within it; such a mycelium is known as a **coenocyte.** The septate mycelium contains many hyphal cells, and each cell contains a uninucleate, binucleate, or multinucleate protoplast.

Among higher fungi the life cycle consists of two phases: (a) **monocaryon phase,** in which the mycelium consists of hyphal cells which are regularly uninucleate, and (*b*) **dicaryon phase,** with binucleate cells. In some cases, the nucleus of uninucleate and binucleate cells divide several times so that the hyphal cells become multinucleate.

The fungal protoplast consists of a granular or reticulated cytoplasm, which, in the older region, leaves a vacuole in the middle of the cell. The nucleus may show a delicate nuclear reticulum with one or more nucleoli, its contents contracted into a dense chromatin body surrounded by a hyaline area. The division of the nucleus is mitotic as well as meiotic.

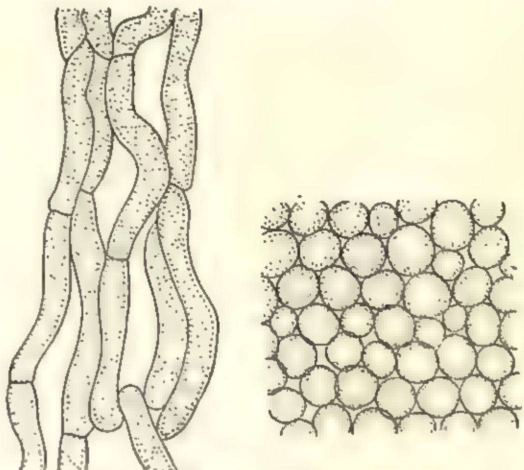
In some cases, the cell wall is made up of pure cellulose, but in others little cellulose is present, the greater part of the wall being a complex fatty acid with a chitin base.

Owing to the absence of the photosynthetic pigments, fungi accumulate carbohydrate reserves, such as sugars and glycogen instead of starch. Oils and proteins are also found as reserve materials. The fungal protoplast also secretes various types of enzymes during its activity, and these not only help the fungus to deal with reserve materials but also assist the parasitic fungi to enter or break down the tissues of the host.

In many cases the hyphae grow together, intertwine, adhere and form a thick tissue, called the **plectenchyma.** It is of two types: (a) **prosoplectenchyma** or **prosenchyma,** when in a tissue the single hyphal elements are recognizable, and (b) **para-plectenchyma** or **pseudoparenchyma,** in which the hyphal individuality

is entirely lost, so that it appears more or less isodiametric in section, resembling a parenchyma.

When the plectenchyma becomes tuberiform in appearance with a pseudoparenchymatic outer rind and a prosenchymatic central core, it is called a **sclerotium.** A sclerotium is a resting body, with abundant food reserves, which carries the fungus over unfavourable conditions of growth, and on the return of normal conditions either directly develops into a mycelium or gives rise to a fructification. Sometimes plectenchyma is formed chiefly from parallel hyphae forming root-like strands, called **rhizomorphs,** which under suitable conditions give rise to the mycelium.



Prosoplectenchyma   Pseudoparenchyma

Fig. 123. Types of plectenchyma.

Reproduction

Most fungi reproduce by vegetative, asexual and sexual methods.

The fungi may reproduce vegetatively by the fragmentation of the whole thallus or of considerable portions of it. Vegetative cells of some yeasts and also the ascospores and the basidiospores in some higher fungi may give rise to lateral outgrowths, which cut off **buds,** and this process of cell multiplication is known as **budding.**

Asexual reproduction takes place by the production of one or more types of asexual reproductive bodies, called **spores.** Some of these types are formed by the sporophyte at a specific time in the life cycles of higher fungi (Ascomycetes and Basidiomycetes) immediately following reduction division of the spore mother-cells. When formed within (endogenous) the mother-cells, they are called **ascospores,** and the mother-cell, an **ascus;** when the mother-cell produces spores externally (exogenous),

the spores are termed **basidiospores,** and the mother cell, a **basidium.** These two types of spores actually correspond to the spores of vascular plants. Other types of spores are also formed for accessory methods of multiplication, but do not possess any relation to a sexual process and do not take part in the alternation of generations. They are purely vegetative in nature and produce mycelia, identical with those producing them. These are devices for rapid increase and dissemination of the organisms, and are either produced by the sporophyte (*e.g.*, rusts and a few other Basidiomycetes) or by the gametophyte (*e.g.*, most of the Phycomycetes and Ascomycetes). Some of the principal types of these accessory spores are: (1) **chlamydospores,** formed by the direct transformation of hyphal cells, or segments of mycelium which become enlarged, thick-walled, filled with food, or portions of the contents of hyphae contract, lose water and become surrounded by thick walls, and act as resting spores; (2) **sporangiospores,** formed within enlarged unicellular sacs, called **sporangia,** due to the successive cleavage of their protoplasts; these spores may be either naked and amoeboid, or are provided with flagella forming free-swimming cells, and are known as **zoospores,** and the sporangia, **zoosporangia.** When the spores, thus formed, become distinctly walled and non-motile, they are termed **aplanospores** or simply **spores;** (3) **conidia,** when cut off externally from the tip of a hypha, fall off and are

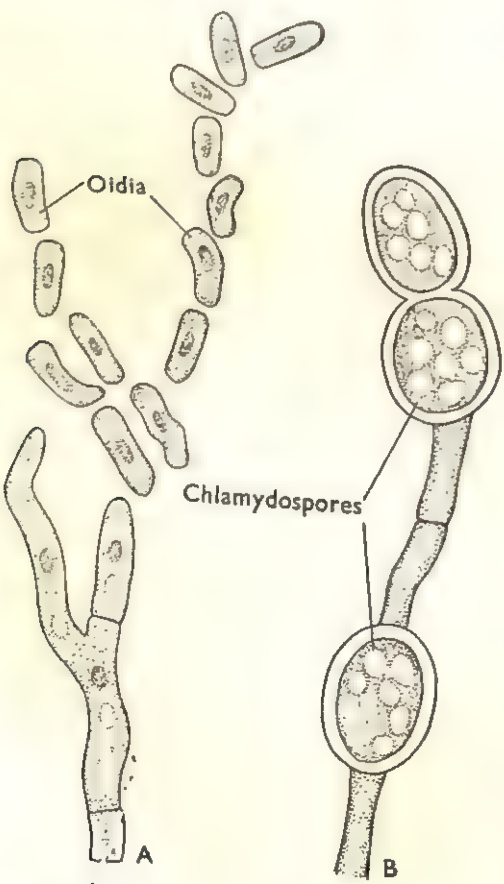


Fig. 124. Oidia and chlamydospores.

disseminated by the wind; and (4) **oidia,** which are another kind of vegetatively formed cells arising directly from the breaking up of a hypha.

Sexual reproduction in fungi is extremely diverse when considered in detail, but when taken as a whole, it shows some evolutionary sequence. Among lower Phycomycetes **isogamy** is represented by the union of two morphologically identical cells, called **gametes,** which fuse in pairs to form a zygote. A somewhat advanced condition is also noticed among Phycomycetes where there is a union of two flagellate gametes of unequal size (**anisogamy**), of which the larger one is regarded as the female cell. The next higher step in the sexual process, when considered in evolutionary sequence, is **oogamy.** In this case, the female gamete (**oosphere** or **ovum**) is a large, non-flagellate, non-motile and passive cell, and the male gamete (**spermatozoid** or **antherozoid**) is a small, flagellate, motile and active cell, as in a few Phycomycetes. Besides these normal processes, there are cases where variations occur. For instance, in some Ascomycetes the male gamete is set free as a naked or very thin-walled, non-motile sperm, which becomes attached to the wall of the oogonium or to a tube-like extension of the oogonium, called the **trichogyne.** Among higher Phycomycetes distinct sperm cells are not produced but only male nuclei are introduced into the oogonium. Sometimes fusion takes place between two gametangia, distinguishable or indistinguishable, whereby the multinucleate protoplasts of the two eventually unite. Among Basidiomycetes, with the exception of rust fungi, sex organs are entirely absent, but the mycelium may exist in two or more sexually differentiated strains. In such cases, any cell of a plant of one sexual phase may unite with any cell of the plant of the opposite sexual phase, as a result of which a sporophytic or diploid (dicaryon) mycelium is produced.

The product of union of gametes is a **zygote** (**zygospore** or **oospore**), depending on the nature of the uniting gametes. Such spores are known as **sexual spores,** which are diploid, and they also take part in the alternation of generations.

Origin of the Fungi

As regards the origin of the true fungi, there are two opposite schools of view. Workers like DeBary (1881), von Tavel (1892), Bessey (1942) and Gaumann (1949) belonging to one school believe

'downy mildews' (*Peronospora*). The lower forms are mostly aquatic and may live either as parasites on plants and animals, or as saprophytes on submerged organic materials. A great majority of them are parasites on terrestrial phanerogamic plants, or they live as saprophytes on various decomposed organic materials. Others are amphibious, occurring as parasites on living organisms, or as saprophytes on damp soil. The vegetative body, when present, is a much-branched coenocytic mycelium but its older portions may sometimes become septate. Asexual reproductive spores, both zoospores and sporangiospores, are produced within unicellular sacs, known as **sporangia,** which are cut off from the tips of hyphae. Some of them may produce conidia and gonidiospores. Sexual reproduction may be isogamous, anisogamous or oogamous, and the plants may be homothallic or heterothallic. When an entire thallus is capable of producing gametes, it is said to be **holocarpic.** But when the gamete production is restricted to the gametangia only, it is referred to as a **eucarpic** thallus. Besides, among some higher forms union between gametangia takes place whereby their undifferentiated, multinucleate protoplasts unite to form a zygote. The zygote, produced as a result of sexual union, forms a thick wall and passes through a period of rest prior to germination.

An outline classification of the Phycomycetes (upto Orders) is given in the following table :

Phycomycetes

Archimycetes	Oomycetes	Zygomycetes
(a) Chytridiales (e.g., *Olpidium*, *Synchytrium*, etc.)	*(a) Blostocladiales (e.g., *Blastocladia*, *Allomyces*, etc.)	(a) Mucorales (e.g., *Mucor*, *Rhizopus*, *Pilobolus*, etc.)
*(b) Ancylistales (e.g., *Lagenidium*, *Ancylistes*, etc.)	*(b) Monoblephari-dales (e.g., *Monoblepharis*)	*(b) Entomophthorales (e.g., *Entomophthora*, *Empusa*, etc.)
*(c) Protomycetales (e.g., *Protomyces*)	*(c) Leptomitales (e.g., *Sapromyces*, *Liptomitus*, etc.)	
	(d) Saprolegniales (e.g., *Saprolegnia*, *Achlye*, *Dictyuchus*, etc.)	
	(e) Peronosporales (e.g., *Albugo*, *Pythium*, *Phytophthora*, *Peronospora*, etc.)	

* Not treated in this book.

The characters of the subdivisions are as follows:

(a) **Archimycetes:** Characterized in having rounded or lobed non-mycelial thallus formed by the enlargement of zoospores, sometimes possessing rhizoids; higher forms may develop a rudimentary mycelium.

(b) **Oomycetes:** Characterized in having a well-developed coenocytic mycelium, often become septate; characteristic mode of sexual reproduction is oogamy, and the zygote is always an **oospore;** accessory spores are mostly motile zoospores formed in most of them.

(c) **Zygomycetes:** Characterized in having a well-developed mycelium, often becoming septate; characteristic mode of sexual reproduction is by conjugation of two gametangia, where undifferentiated contents fuse to form a zygote known as **zygospore;** accessory spores are non-motile aplanospores, known as sporangiospores, formed within a unicellular sac, called the sporangium.

ORDER **CHYTRIDIALES**

The thallus is very variable in form, with or without appendages, mostly holocarpic, producing one or more sporangia or gametangia; zoospores uni- or bi-flagellate and exhibit diplanetism in some cases; zoogametes uniflagellate.

SYNCHYTRIUM

(Fam. SYNCHYTRIACEAE)

There are about 50 species under the genus, of which *Synchytrium endobioticum* is described below. This species is responsible for causing the **wart disease** of potatoes. Usually this parasite attacks the potato tuber at the ground level in spring, and consequently, some gall-like swellings appear on the tubers.

Vegetative body

The thallus is unicellular, endobiotic and holocarpic. The walls are usually composed of chitin.

Reproduction

Synchytrium reproduces both asexually and sexually.

Asexual reproduction takes place by means of uniflagellate zoospores. The zoospore, under suitable conditions, enters into the epidermal cell of the host leaving its flagellum outside the host cell. This spore then settles at the bottom of the cell and

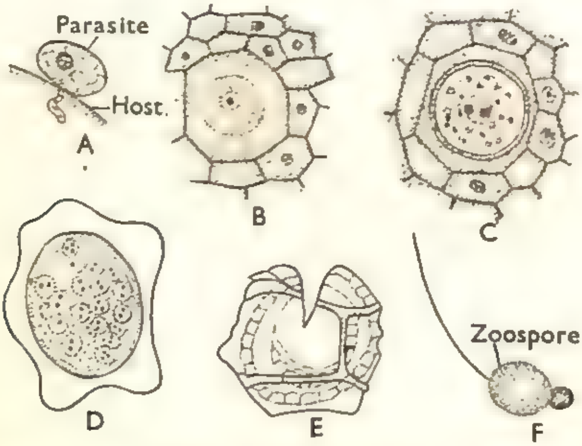


Fig. 125. *Synchytrium*.
A, Infection of the host by the zygote; B—E, Stages in the development of the zoosporangium; F, A zoospore.

enlarges in size by absorbing food from the surrounding protoplasts. It secretes an outer thick and inner thin, cell wall. This structure is known as the **summer spore.** Meanwhile, the surrounding host cells are stimulated by the local infection, and consequently, the cells divide and enlarge in size forming tumours or gall-like outgrowths. The summer spore then germinates inside the host cell, its outer wall ruptures and the protoplast with the inner thin wall pushes out into the upper portion of the host cell. Its nucleus divides repeatedly forming 32 nuclei, and this multinucleate structure is known as the **prosorus.** Subsequently, the prosorus is divided into four to nine multinucleate segments by cleavages. The individual segment is known as the **sporangium** or **gametangium,** depending on the environmental conditions. When the moisture content is very high, then each segment of the prosorus acts as a **zoosporangium** or **summer sporangium.** The nucleus of the sporangium divides forming two hundred to three hundred nuclei, and the entire protoplast of the sporangium becomes segmented into a number of smaller blocks. Each block consisting of a nucleus with the surrounding cytoplasm develops into a uniflagellate **zoospore.** When the zoospores attain maturity, the

sporangium comes out of the prosorus, and the zoospores are discharged through the papilla in presence of a film of water and initiate new infections.

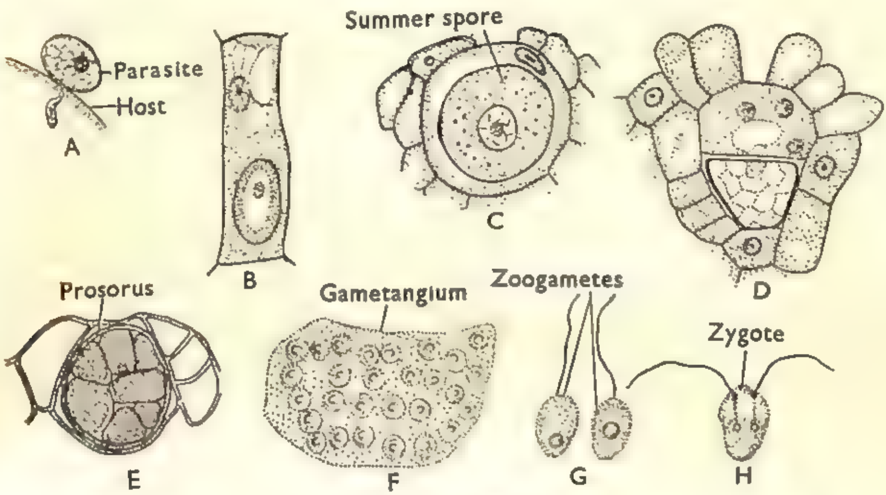


Fig. 126. *Synchytrium*.
A, Infection of the host by a zoospore; B, Zoospore within the host cell; C—F, Stages in the formation of the gametangium; G, Zoogametes; H, A zygote.

When moisture is lacking, the segment of the prosorus acts as a gametangium and the gametes, which are produced inside the gametangium, are known as **zoogametes.** The zoogametes of different gametangia may unite to form a biflagellate zygote. The zygote then retracts its flagella and secretes a thin wall. This zygote may infect the host plant like a zoospore. The zygote again forms a thick wall round it within the host cell and acts as the resting sporangium. Its protoplasts divide in the next spring and form zoospores, which ultimately escape and infect another plant.

ORDER **SAPROLEGNIALES**

Mostly aquatic fungi, sometimes terrestrial; parasitic on animals as well as plants; mycelium aseptate and branched; hyphae not constricted at intervals; cell wall contains cellulose; zoospores biflagellate and usually exhibit diplanetism; sexual reproduction oogamous; an oogonium contains one to many eggs.

SAPROLEGNIA

(Fam. SAPROLEGNIACEAE)

Saprolegnia and its allies are often known as 'water moulds', because they are commonly found growing in water saprophytically upon dead bodies of insects, or upon other animals, or plant remains. They can also grow on surface soils, and some of them are active parasites on angiosperms.

Vegetative body

The mycelium is typically coenocytic, consisting of much-branched hyphae, which contain multinucleate, granulated and vacuolated protoplasm. The hyphae are usually long, but some of them, which penetrate the substratum, are short and function like rhizoids.

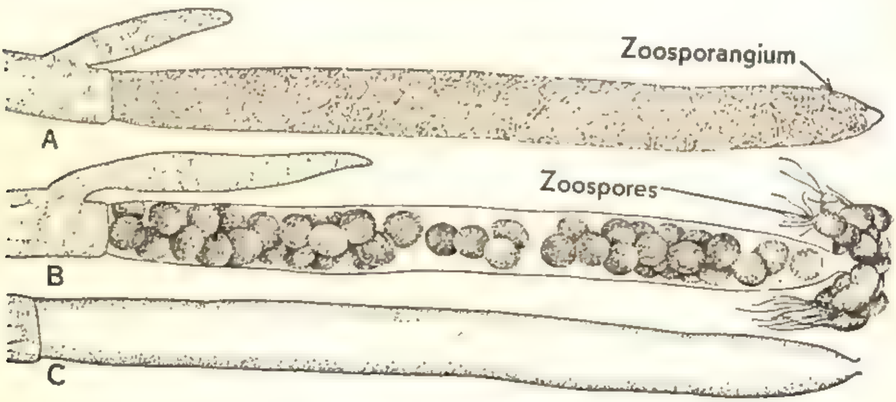


Fig. 127. *Saprolegnia.*
A, A zoosporangium; B, The same liberating zoospores; C, An empty zoosporangium after the liberation of its contents.

Reproduction

Saprolegina reproduces both asexually and sexually.

Asexual reproduction takes place by the formation of zoospores, within zoosporangia, formed at the apices of the hyphae. During the development of a zoosporangium, the apical portion of a hypha slightly enlarges, and there is an accumulation of cytoplasm and nuclei within it. It is then cut off from the rest of the hypha by the formation of a transverse wall. Its multi-

nucleate protoplast by progressive cleavage is divided into uninucleate zoospores. Each zoospore is pear-shaped with two flagella at the narrow anterior end. Finally, the zoospores escape through an exit pore, formed at the apex of the sporangium, and begin to swim in water. After a period of activity, each zoospore comes to rest; its flagella disappear, rounds up, secretes a wall round it and passes into a resting period. This resting period is of a very short duration, and when the period is over, its protoplast comes out as a zoospore through a pore in the wall and starts swimming again, but in another form. This time it is kidney-shaped with two lateral flagella attached to its concave side. This

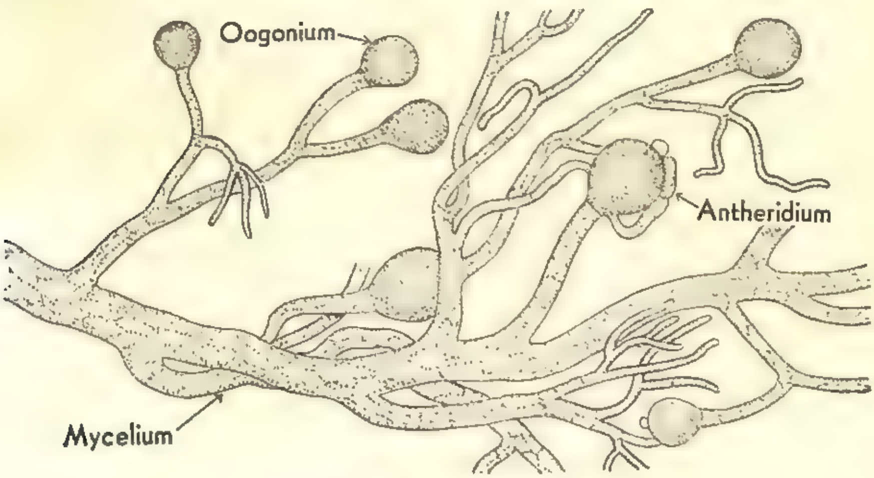


Fig. 128. *Saprolegnia.*
A portion of the mycelium showing young sex organs.

phenomenon is known as **diplanetism.** The kidney-shaped zoospore, after swimming for a short period, comes to rest, rounds up, secretes a wall around it and directly germinates to form a germ tube, which ultimately ramifies and forms a new mycelium.

After the zoospores have escaped from a sporangium, its base may proliferate inside the empty sporangium forming a new sporangium which again gives rise to zoospores. This process may be repeated a few times. As a result, the sporangia, which are formed in succession, lie enclosed one within the other, and the mode of escape of zoospores is referred to as the **repeated emergence.**

Some species of *Saprolegnia* regularly form *chlamydospores* in a chain at the apices of the hyphae and germinate directly into new mycelia.

In some cases, a hypha undergoes direct division forming spore-like bodies, called **gemmae,** which are usually produced terminally in a altenate series but may also be intercalary in position.

Sexual reproduction is oogamous. All the species of *Saprolegnia,* so far investigated, have been noted to be homothallic. Sex organs, antheridia and oogonia, are borne terminally at the apices of the hyphae. During the development of an oogonium the apical portion of a hypha swells up and forms a globular structure into which some amount of cytoplasm and many nuclei flow.

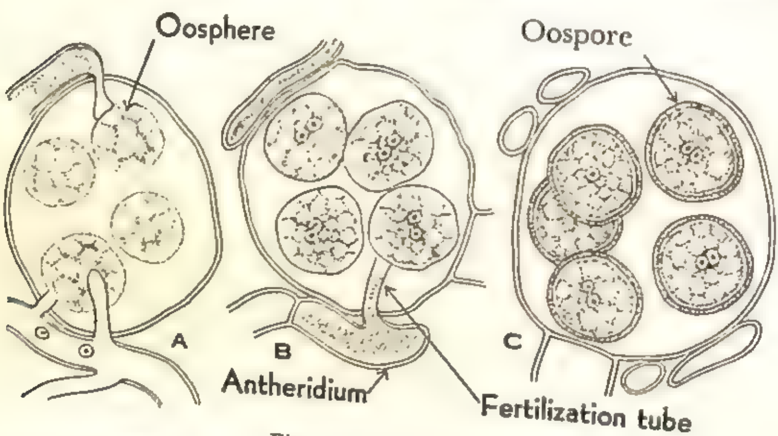


Fig. 129. *Saprolegnia.*
A—C, Stages in the development of sex organs and fertilization.

This is then cut off from the rest of the hypha by the formation of a transverse wall. Oogonia may be formed either at the apex of the main strand of hypha or at the apices of its branches. Soon there appears a central vacuole in the protoplast of the oogonium, and as it enlarges it presses the peripheral protoplasm against the wall of the oogonium. The nuclei divide in the peripheral region and some of these degenerate. By progressive cleavage this protoplasm is cut into uninucleate blocks, which round up and form several oospheres or eggs (1-20). The oospheres lie free in the oogonium, and there is no residual cytoplasm within it.

Similarly, antheridia also develop at the apices of the hyphal branches, usually located nearby. Such species are called **diclinous.**

In other cases, they are **androgynous,** because antheridial branches develop from the stalk of the oogonium. This shows that the species are homothallic, although there is the possibility for a few species to be heterothallic also. Antheridial development begins with the enlargement of the terminal portion of an antheridial branch, and this portion is cut off by the formation of a transverse wall. Its protoplasm contains several male nuclei.

A contact between the antheridium and the oogonium is brought about by the curvature of the antheridial hypha, so that the antheridium is applied to the wall of the oogonium. Sometimes the

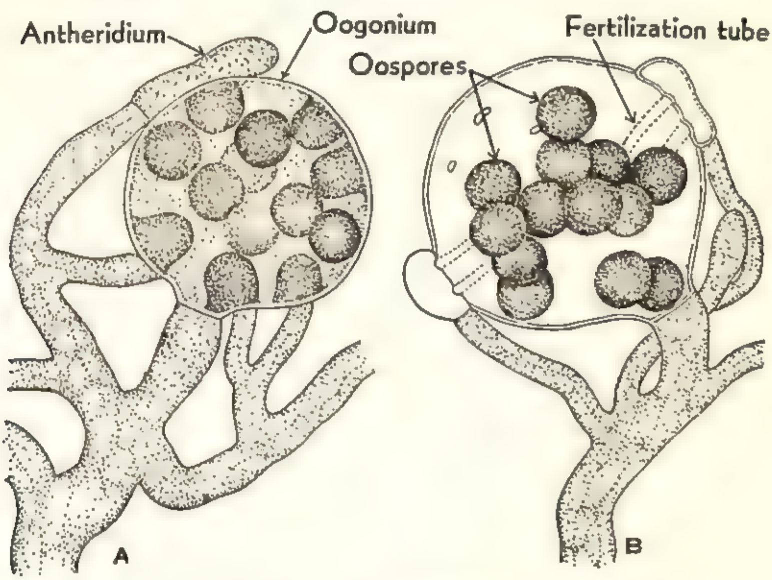


Fig. 130. *Saprolegnia.*
A, Mature sex organs; B, Formation of oospores after fertilization.

antheridial hypha branches, and each branch forms a separate antheridium, so that several antheridia come in contact with the oogonial wall. A fertilization tube from each antheridium penetrates the wall of the oogonium, reaches an oosphere and emits its protoplasmic contents. Only one male nucleus fertilizes the oosphere which rounds up, secretes a thick wall around it and forms an oospore. Similarly, male nuclei from other antheridia fertilize other oospheres forming oospores. Each oospore has a thick **epispore** and a thinner **endospore** and contains brown or yellowish fat materials as reserve food. The mature oospore germinates

after a period of rest; its epispore ruptures and the endospore elongates to form a long germ tube, which either directly invades the substratum, or with or without branching becomes terminated by a zoosporangium. It is assumed that the zygote nucleus probably divides reductionally at the time of germination.

ORDER **PERONOSPORALES**

Mostly parasitic on land plants, some being saprophytic; same structure functioning either as a zoosporangium or as a conidium, depending on environmental conditions; zoospores biflagellate; sexual reproduction oogamous; an oogonium contains a solitary egg and well-defined periplasm.

PYTHIUM

(Fam. PYTHIACEAE)

There are several species of *Pythium* responsible for some of the important diseases of crop plants, of which *Pythium de Baryanum*, a destructive parasite, causes **damping off** disease resulting in the death of young seedlings in our country. The fungus lives in the soil and attacks the seedling at the ground level, the tissues are softened and destroyed, and the seedlings suddenly fall over. Under favourable conditions the percentage of loss in a plantation may be very high.

Vegetative body

The fungus produces a much-branched, hyaline, coenocytic mycelium with hyphae evenly attenuated towards their apices. When the mycelium becomes old, septa do appear even in the coenocytic mycelium, particularly during the formation of the reproductive bodies. Within the tissues of the host the mycelium ramifies in all directions through the intercellular spaces, but intracellular hyphae are not uncommon.

Reproduction

The fungus reproduces both asexually, by the formation of conidia and zoospores, and sexually by the union of heterogametes to form oospores.

At the time of asexual reproduction, some of the hyphae, projecting from the substratum, bear globular sporangia, which are cut off from the supporting hyphae by transverse walls. When these structures grow in the air, they germinate *directly* by putting forth germ tubes and thus behave as **conidia.** The germ tubes ramify and form new mycelia. If, on the other hand, they grow in wet conditions, such as on substrata in shallow water, their *indirect* germination by the formation of zoospores takes place, and

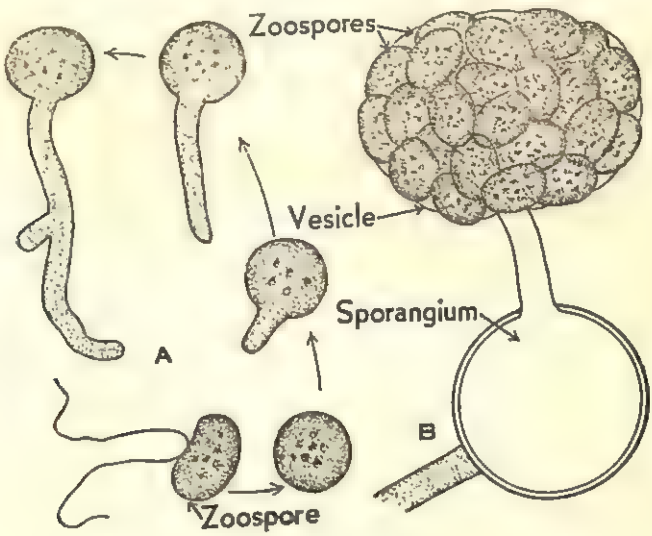


Fig. 131. *Pythium.*
A—B, Formation and germination of zoospores.

then they behave as **sporangia.** The contents of each sporangium undergo cleavage to form zoospores. During the formation of zoospores, the sporangium puts forth a lateral tube, whose apical portion swells considerably to form a vesicle, and the contents of the sporangium pass into it. Within the vesicle the organization of the zoospores is completed. Eventually, the vesicle bursts and several kidney-shaped zoospores, each with two lateral flagella, are liberated. After a period of activity, each zoospore comes to rest, rounds up, secretes a wall around it, germinates by putting forth a germ tube and brings about infection of a new host.

The fungus reproduces sexually when it lives as a saprophyte after killing its host. It is oogamous and both antheridia

and oogonia are produced on the same thallus (homothallic). The oogonium is a globular structure, which develops terminally on a lateral branch, and is cut off from the latter by the formation of a transverse septum. From the stalk of the oogonium a branch develops, at whose apex an unicellular antheridium is cut off. Due to the curvature of the antheridial stalk, the tip of the antheridium becomes applied to the side of the oogonium, and the antheridium is said to be **paragynous.**

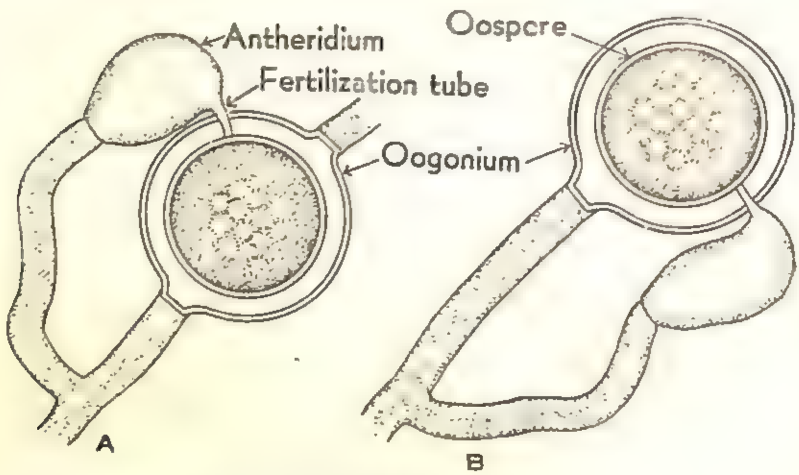


Fig. 132. *Pythium.*
A—B, Stages in the process of fertilization and formation of oospore.

Both oogonia and antheridia contain dense cytoplasm and many nuclei. The protoplasm of the oogonium becomes differentiated into a central multinucleate **ooplasm** and a peripheral **periplasm** with a few nuclei. The nuclei of the ooplasm migrate into the periphery and divide once; all but one of the daughter nuclei degenerate and the remaining one with its surrounding cytoplasm forms the oosphere or egg. The nuclei of the antheridium also divide once and a single male nucleus survives after the degeneration of the supernumerary nuclei. A **fertilization tube** passes from the antheridium to the ooplasm, opens and emits the male nucleus together with some cytoplasm. The male and female nuclei fuse and a thick-walled oospore is formed. After a period of rest, the oospore germinates by the formation of germ tubes.

PHYTOPHTHORA

(Fam. PYTHIACEAE)

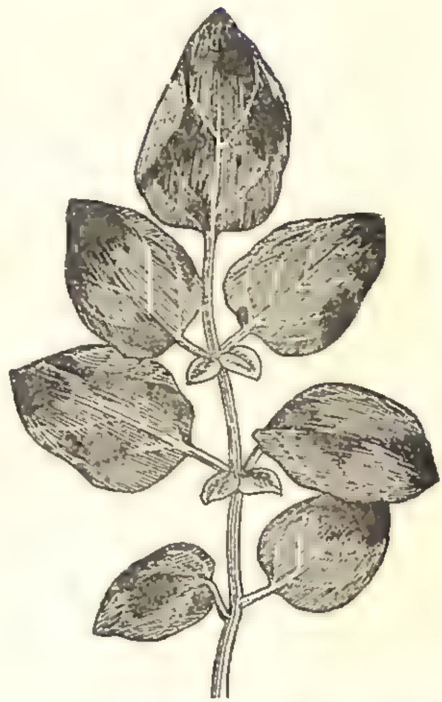


Fig. 133. *Phytophthora infestans*. Leaves of potato showing terminal and marginal infections of 'late blight'.

The species of *Phytophthora* usually occur as parasites on terrestrial flowering plants, but also live as saprophytes. Of these species, *P. infestans* causes a disease known as **late blight** and **rot** of the potato, the most serious of all potato diseases. The aerial parts of plants, particularly the leaves, are attacked and as a result these are gradually killed and dried up causing a blight, but sometimes the tubers are also invaded making soft or dry rots.

Vegetative body

The vegetative body or the mycelium of *P. infestans* is a coenocyte, which lives in the intercellular spaces of the host tissue. It draws nourishment from the adjacent living cells by short specialized hyphal branches, known as **haustoria,** which penetrate them.

Reproduction

P. infestans reproduces both asexually and sexually.

At the time of asexual reproduction slender aerial septate hyphae come out through the stomata in groups from the internal mycelium. These are known as **conidiophores.** The conidiophore is sympodially branched and bears conidia at the tips of its branches. Each **conidium** is ovoid or lemon-shaped and thick-walled, and has a thin-walled, hyaline, apical papilla. It contains multinucleate and granulated protoplasm with several vacuoles and oil drops as food-reserves. At maturity, the conidium

germinates in two ways, and the type of germination is influenced by the conditions of temperature, moisture and substratum.

When the temperature condition is comparatively high and there is less of moisture, the conidium germinates directly by putting forth one or more germ tubes, which penetrate the host tissues through the stomata of the leaves or stems, or by breaking through

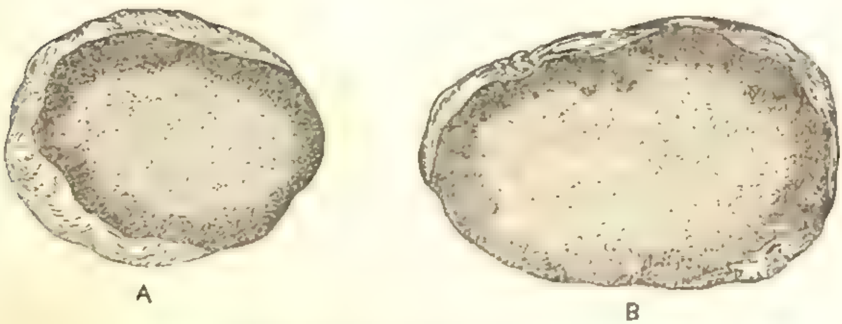


Fig. 134. *Phytophthora infestans.*
A—B, Sections through potato tubers affected with 'late blight' rot.

the epidermis. But, when there is excessive moisture and the temperature condition is low, the conidium behaves like a **zoosporangium.** Its multinucleate protoplast, by progressive cleavage, forms biflagellate zoospores. At maturity, the apical papilla of the zoosporangium dissolves and the zoospores come out through the terminal pore. Each zoospore, after a period of activity, settles down, rounds up and puts forth a germ tube, which brings about infection of the host plant as stated before. The infection of the tubers probably takes place directly through the lenticels.

When this fungus is grown artificially on culture media, the mycelium often forms thick-walled **chlamydospores.** Each chlamydospore is more or less spherical, terminal or intercalary, with numerous oil drops as food-reserves. On germination a chlamydospore either produces an extensive mycelium or one or more simple or branched hyphae on which conidia or zoosporangia are borne.

P. infestans is homothallic and oogamous. Normally sex organs do not appear to form in the host, but they have been obtained in abundance in artificial culture.

The sex organs, antheridium and oogonium, are borne at the tips of specialized hyphal branches, which, when very young, cannot be

readily distinguished from each other. However, the two branches grow towards each other, and the tip of the female branch penetrates the apex of the male branch. The apical portion of the male

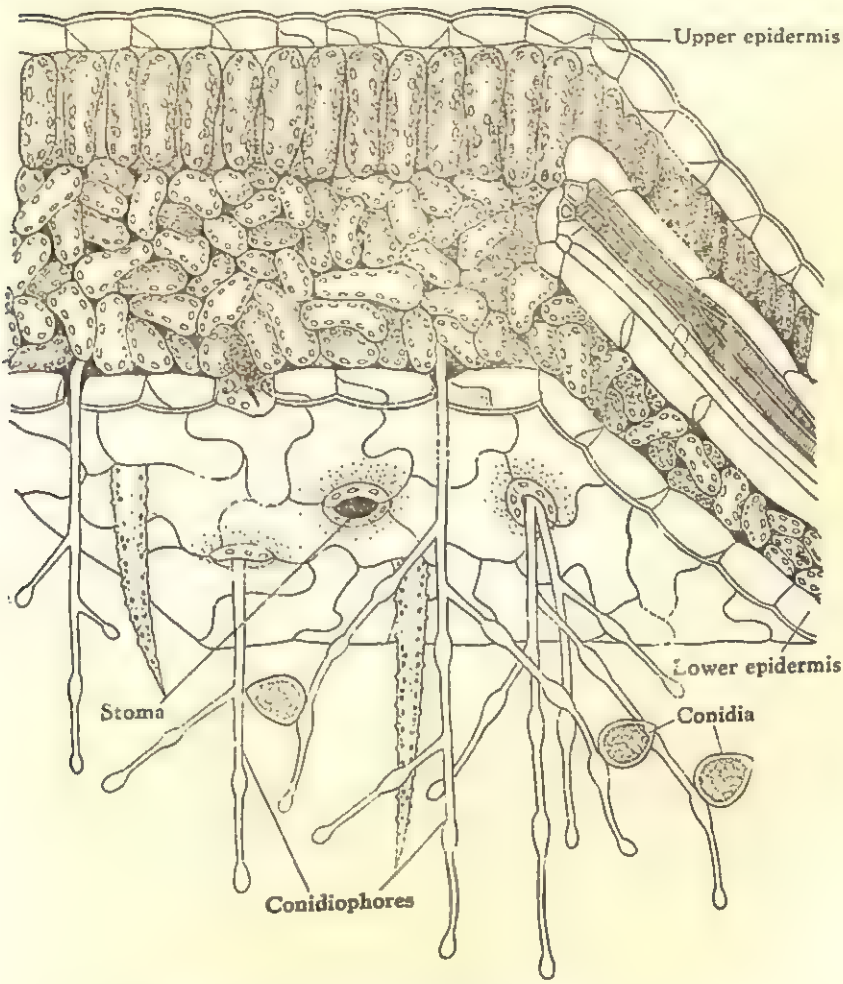


Fig. 135. *Phytophthora infestans.*
A three-dimensional diagram of a part of an infected leaf of potato showing the fungus emerging through the stomata and successive stages in the development of conidiophores and conidia.

branch, with its densely accumulated protoplasm, is cut off by the formation of one or two transverse septa forming an antheridium. Meanwhile, the tip of the oogonial branch grows through the

antheridium and comes out on its other side forming a rounded swelling. This is the young oogonium, which contains granulated cytoplasm and many nuclei. The base of the oogonium is funnel-shaped and it lies within the antheridium. This type of antheridium is known as **amphigynous.** The oogonium is separated

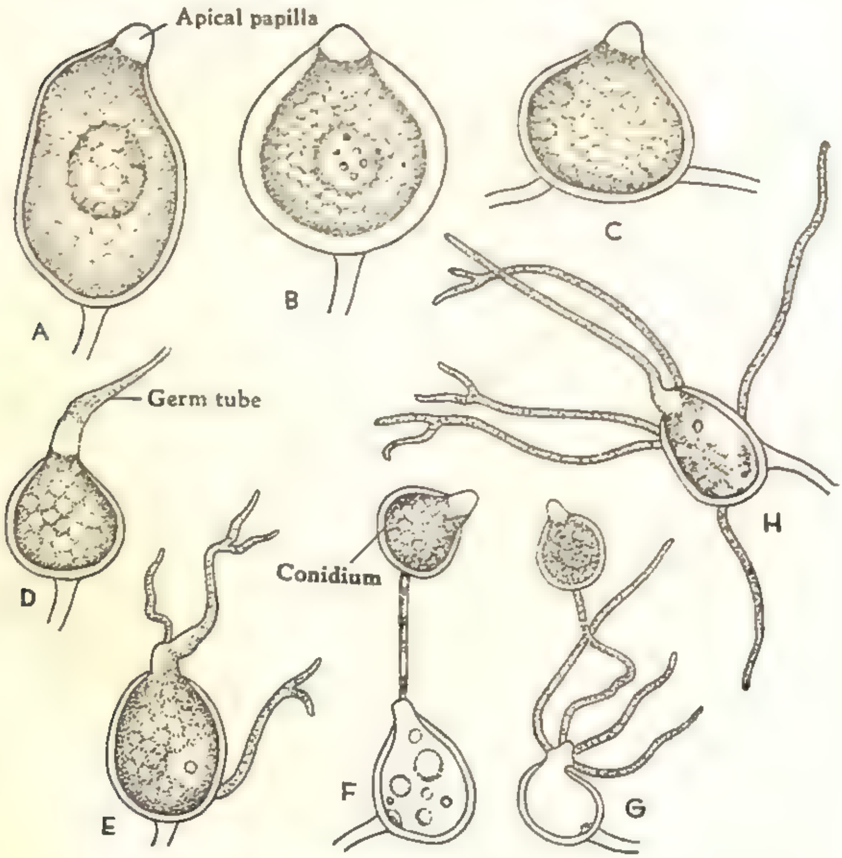


Fig. 136. *Phytophthora.*
A—C, Different types of conidia; D—E and H, Stages in germination of a conidium; F—G, Conidia germinating and producing secondary conidia in artificial culture.

from the rest of the hypha by the formation of an irregular **plug** at its base.

Most of the nuclei of the oogonium degenerate and the remaining ones divide, undergo further disintegration with the exception of one nucleus, around which cytoplasm collects and an oosphere is

formed. A peripheral layer of cytoplasm surrounding the oosphere is also recognizable, and is known as the **periplasm.** Similarly,

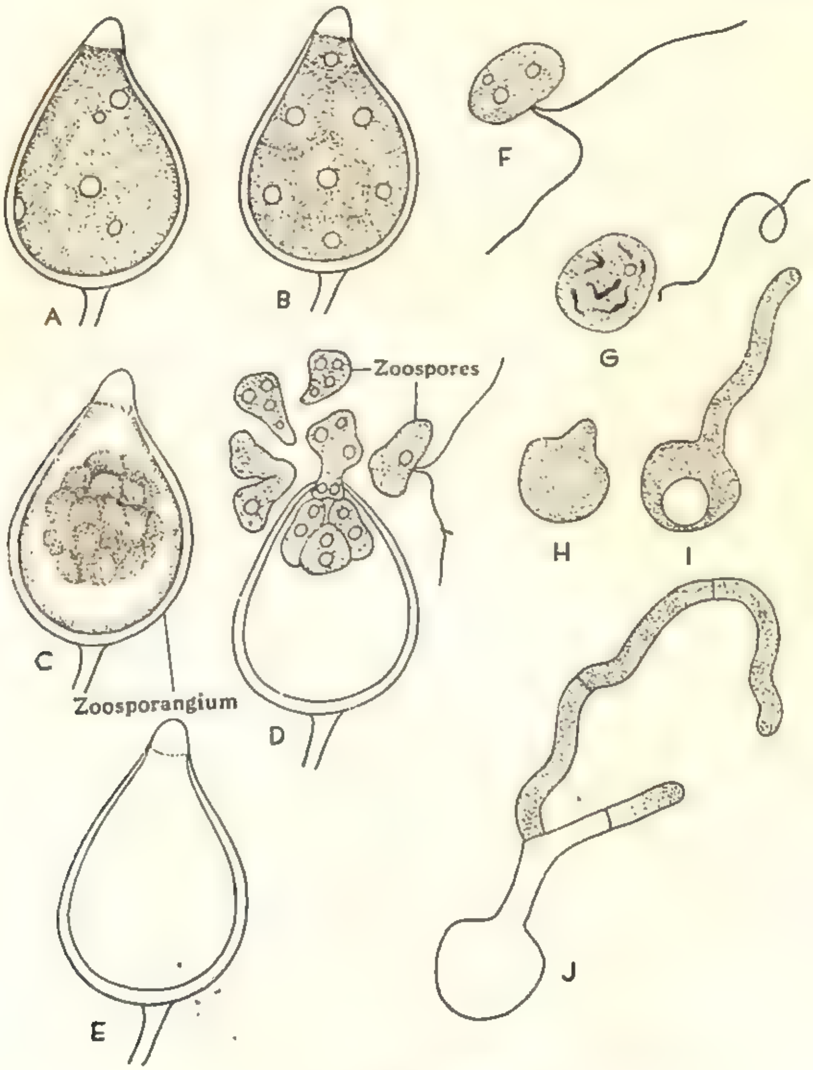


Fig. 137. *Phytophthora.*
A—E, Stages in the germination of zoosporangium and formation of zoospores; F, A zoospore; G—J, Germination of a zoospore to form infection threads.

the antheridial nuclei also divide and then all but one disintegrate. Soon there follows the formation of a fertilization tube through which the male nucleus and some cytoplasm are delivered to the oosphere.

Fertilization follows, the male and the female nuclei fuse to form an oospore. The oospore, after a period of rest, germinates and gives rise to a short hyphal system on which sporangia are borne.

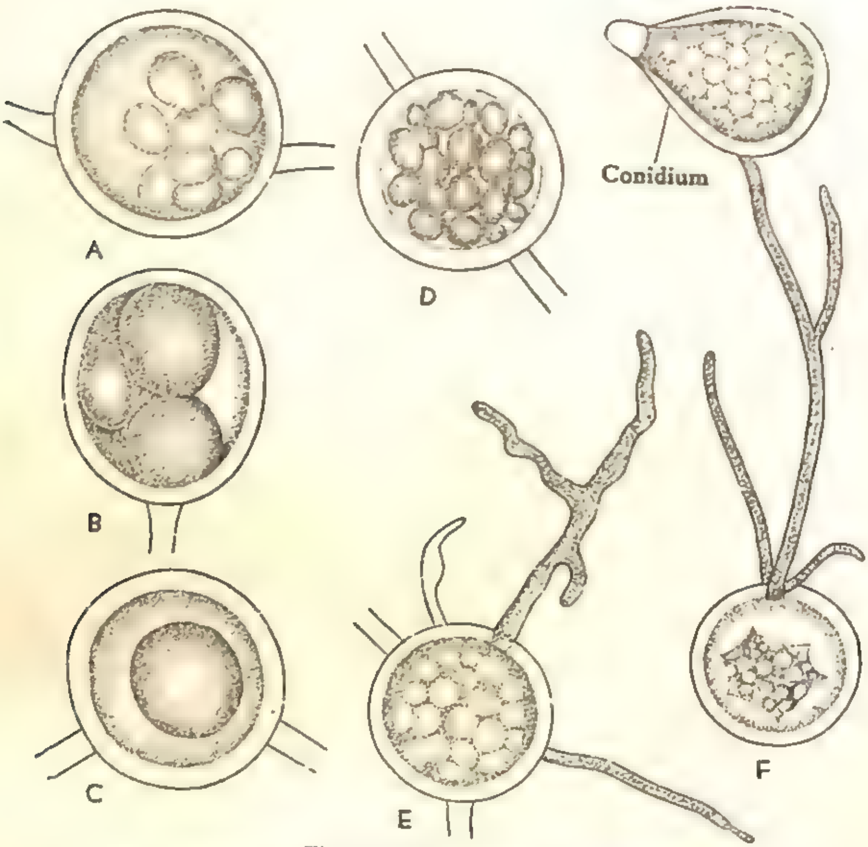


Fig. 138. *Phytophthora*.
A—D, Kinds of chlamydospores; E—F, A germinating chlamydospore producing a secondary conidium in artificial culture.

Control measures

The disease caused by *Phytophthora* can be effectively controlled by spraying or dusting with a fungicide. A fungicide is a chemical substance which is toxic to the fungi and possessing killing or inhibiting effect on the parasite without injuring or disfiguring the host plant. The sprayings of Bordeaux mixtures (copper sulphate, lime and water in varying proportions), or dusting with copper-lime dust (dehydrated copper sulphate, hydrated lime and calcium

arsenate) have given increased yields, better control of fungi and insects, and lessened the physiological defects. Besides these, there

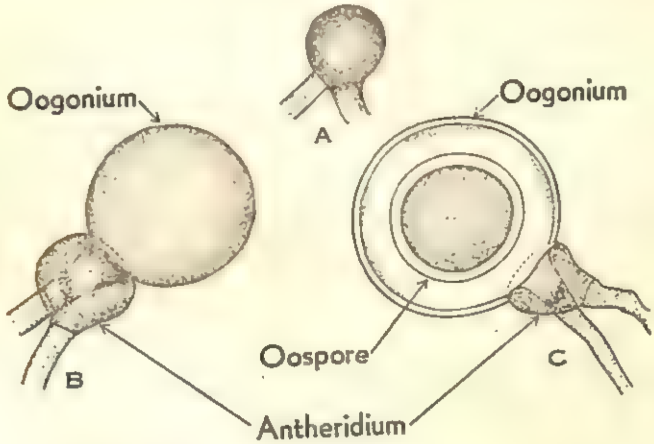


Fig. 139. *Phytophthora*.
A—C, Stages in the development of antheridium and oogonium and formation of oospore; A, Oogonial incept pierces the antheridial branch; B, Emergence of the oogonial incept and formation of a young oogonium; C, A ripe oospore within the oogonium with the empty antheridium attached to its base.

are other methods, such as, selection of healthy seeds at the time of sowing, or by storing the tubers at low temperatures (at or below 40° F.), which can prevent the spread of the disease.

ALBUGO

(Fam. Albuginaceae)

Albugo candida, formerly known as *Cystopus candidus*, is a most common species causing **white rust** of cruciferous plants throughout the world. It is an obligate parasite, which forms white shining patches on stems and leaves, and causes much deformation of the inflorescences and fruits.

Vegetative body

It is a much-branched, intercellular, coenocytic mycelium with rather coarse hyphae, which bear numerous small, rounded, intercellular haustoria within the neighbouring cells.

Reproduction

Albugo reproduces both asexually and sexually.

During asexual reproduction, hyphae collect beneath the epidermis and form closely-packed groups of simple or branched,

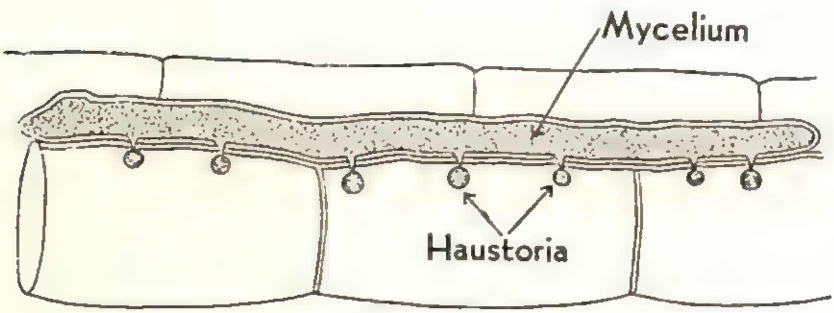


Fig. 140. *Albugo*.
Part of the mycelium bearing haustoria.

club-shaped structures (**conidiophores** or **sporangiophores**) forming a palisade-like layer, which pushes the epidermis outwards to form whitish blister-like areas, called **sori.** Each club-shaped structure cuts off successively from its apex, a chain of globular

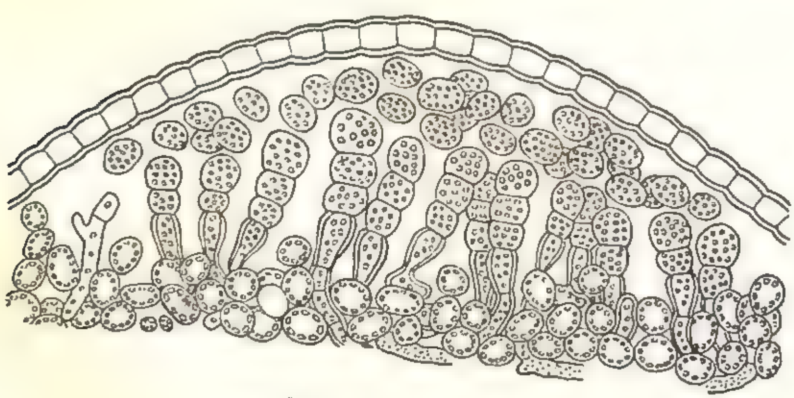


Fig. 141. *Albugo*.
Development of conidia (sporangia).

bodies (**conidia** or **sporangia**), each with five to six nuclei. They are separated from one another by short neck-like projections of some gelatinous material. As the chains elongate, they press the

epidermis above and ultimately it becomes ruptured. The globular structures successively break off and are easily disseminated by the wind.

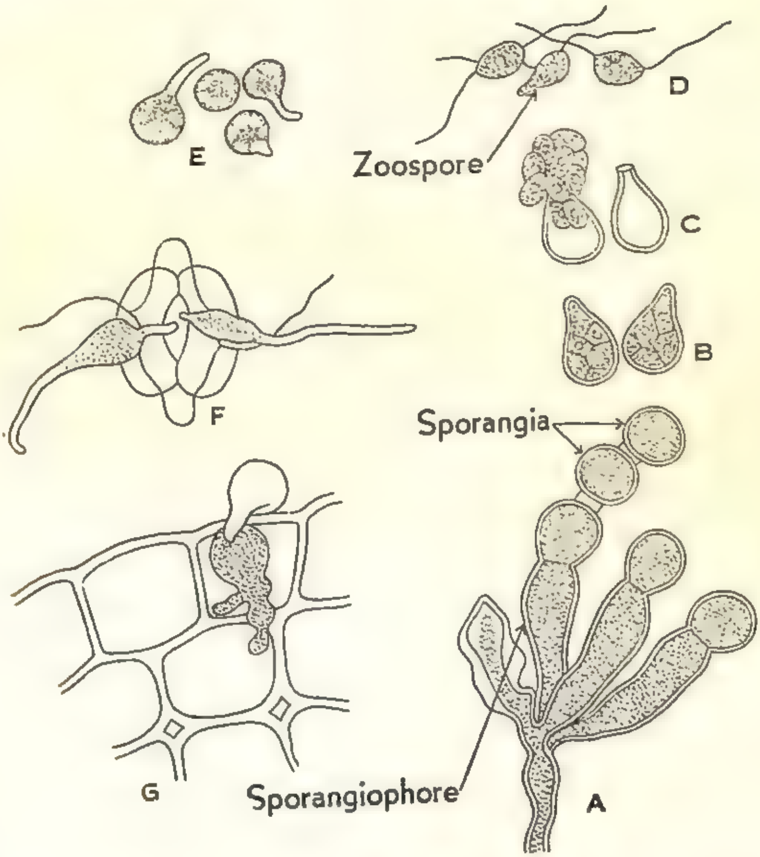


Fig. 142. *Albugo.*
A, A group of sporangiophores with sporangia; B—C, Germination of sporangia; D, Zoospores; E, Germination of zoospores; F, Germ tubes entering through a stoma; G, Formation of haustoria.

Each globular body, under favourable conditions, germinates directly by the production of germ tubes and behaves as a conidium, or indirectly by the production of zoospores and functions as a sporangium. In presence of water and a low temperature, the zoospores are produced, but in a relatively dry condition the germ tubes are formed. In the latter case, the germ tube may enter into various parts of plants and bring about infections.

When germination takes place indirectly, the contents of a sporangium, by the process of cleavage, form 4-8 zoospores, which either escape, one by one, through a pore formed on the wall of the sporangium, or an adherent mass of zoospores is discharged into a vesicle formed by the sporangium itself. The vesicle eventually disappears and the zoospores are set free. The zoospores are ovate to slightly kidney-shaped in form and each bears two unequal

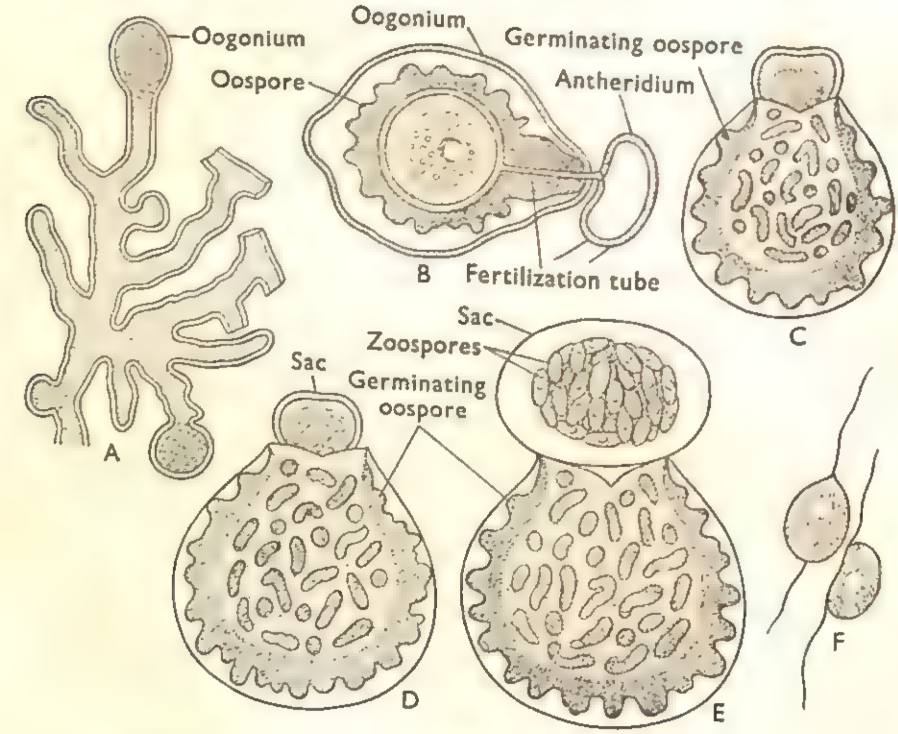


Fig. 143. *Albugo*.
A, Young oogonium; B, Formation of oospore; C—E, Germination of oospore; F, Zoospores.

flagella. After a period of swimming, a zoospore comes to rest, its flagella disappear and a wall is secreted around the protoplast. It then germinates directly by forming a germ tube, which usually enters through a stoma and brings about infection.

Sexual reproduction takes place by oogamy. Both antheridia and oogonia develop within the host tissues, particularly in those of the flowers and axes of the inflorescences. The sexual process is essentially similar to that of *Pythium de Baryanum* but differing

in details. In this case, more periplasm is formed and the female nucleus lies in a deeply-stainable mass of cytoplasm at the centre of the ooplasm. After fertilization when the zygote is formed, the zygote nucleus divides, soon after its formation, into about 32 nuclei so that the resting oospore is multinucleate. There is evidence that the reduction division takes place during the division of the zygote nucleus. Under favourable conditions when the oospore germinates, its outer wall ruptures partly exposing an internal transparent sac-like structure containing zoospores. This sac finally ruptures and biflagellate zoospores are set free, which may eventually bring about infection.

PERONOSPORA

(Fam. Peronosporaceae)

The genus *Peronospora* includes about 75 species. Almost all the species are obligate parasites. They are responsible for a common plant disease, generally known as **downy mildews.** The appearance of thin and greyish-white downy patches on the under surface of the leaf justifies the name of the disease. The other symptoms as localized yellow or brown spots, are also noticeable on the dorsal surface of the leaf. Of various mildews, **downy mildew** of crucifers caused by *Peronospora parasitica* is described below. This is widely distributed in Europe, America and also in India, particularly on cabbage, cauliflower, radish and turnip. All these host plants usually remain stunted when they are attacked with mildew.

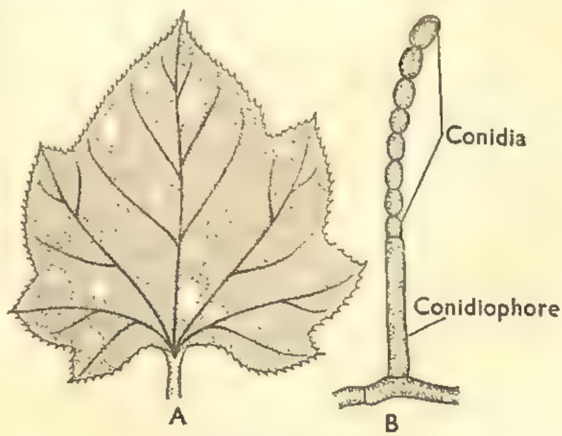


Fig. 144. *Peronospora*.
A, A cucurbit leaf infected with the pathogen;
B, Formation of conidia in chains on a conidiophore.

Vegetative body

The mycelium is typically coenocytic, consisting of much-branched hyphae. These hyphae usually ramify in the intercellular spaces of the host cells. It draws nourishment from the adjacent living cells by means of haustoria.

Reproduction

Peronospora reproduces both asexually and sexually.

At the time of asexual reproduction several **conidiophores,** developed from the intercellular mycelium, emerge through the stomata on the ventral surface of the leaves. Subsequently, they elongate considerably and bifurcate 6-8 times at the apex and the ultimate branches bear **conidia** at their tips. The conidia are

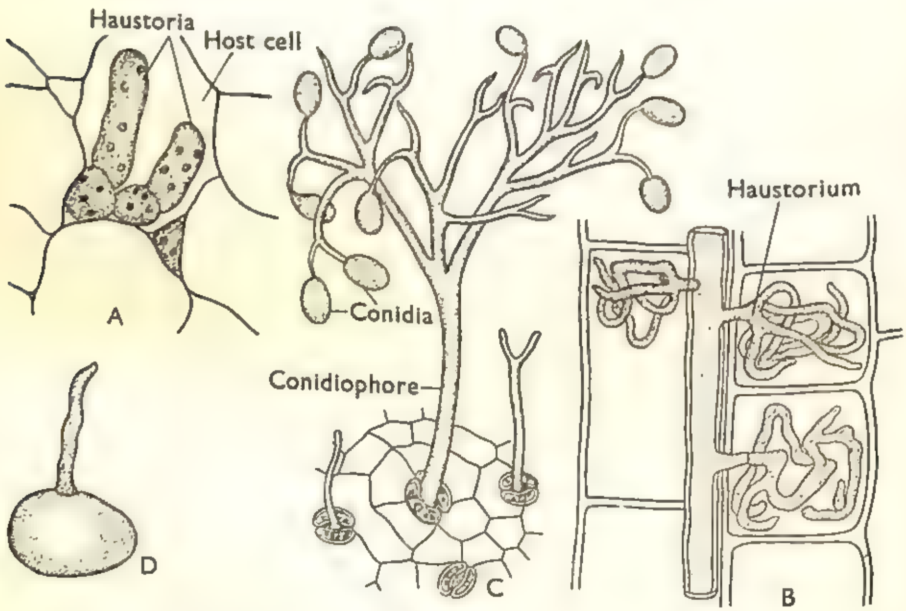


Fig. 145. *Peronospora*.
A, Haustoria within the host cell; B, Ramification of haustoria into finger-like processes within host cells; C, Emergence of conidiophores through the stomata, and the formation of conidia; D, A germinating conidium.

usually oval, sometimes spherical, hyaline and uninucleate. Eventually, these conidia are disseminated by the wind, and when fall on suitable host, they germinate under favourable conditions and give rise to germ tubes from indeterminate points on the sides of the conidia. The germ tubes usually enter into the host through the

stomata, or direct penetration of the epidermal cells of the host plants.

Sexual reproduction is oogamous. In this case well differentiated antheridia and oogonia are developed from the nearby hyphae. The antheridium is multinucleate in the beginning, but gradually all the nuclei except one degenerate. The remaining nucleus acts as the male nucleus. On the other hand, the oogonium is also multinucleate at the early stage but with further development, it becomes differentiated into central uninucleate **oosphere** and peripheral multinucleate **periplasm.** During gametangial contact, a fertilization tube is formed by the antheridium which penetrates the periplasm and finally discharges the male nucleus into the oosphere. The male nucleus then fuses with female nucleus and consequently, a zygote is formed. After fertilization, the zygote develops a thick wall and after a period of rest inside the host or in the soil, it germinates by producing germ tubes under favourable conditions, and initiates fresh infection. Possibly, the first nuclear division is reductional inside the zygote.

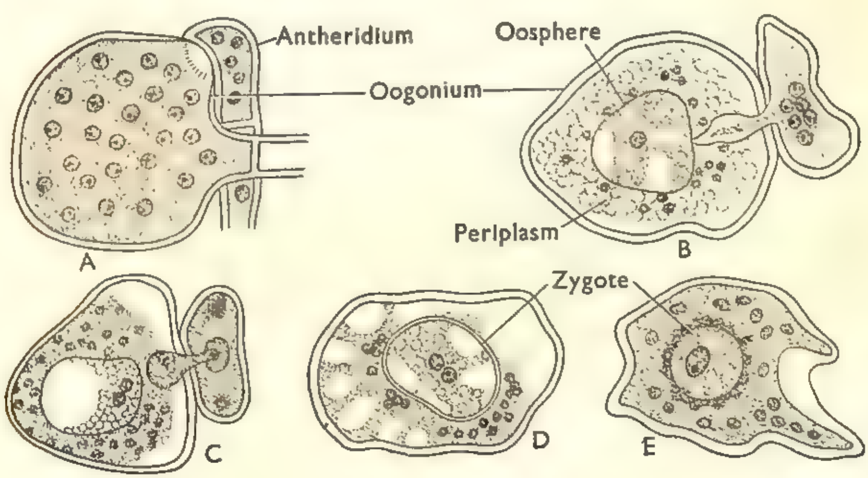


Fig. 146. *Peronospora.*
A—E, Stages in the formation of the zygote.

Control measures

The disease may be partially controlled by spraying with chloranil (spergon) and zinc sulphate, and crowding plants should be avoided.

ORDER **MUCORALES**

Mostly saprophytes on various substrata, rarely parasitic; mycelium coenocytic, at first aseptate and very regular, but irregular and septate with age; asexual reproduction by means of sporangiospores ; sexual reproduction by the union of multinucleate morphologically alike gametangia; mostly heterothallic, may be homothallic also.

MUCOR

(Fam. MUCORACEAE)

Mucor mucedo, commonly known as mould, is frequently found as a saprophyte on decayed and rotten organic matters, particularly if the medium is rich in starch and sugars. It forms a white, cottony growth of mould on horse dung, preserved fruits, cheese, moist leather, etc., usually during the rainy season.

Vegetative body

The vegetative body of the fungus, which is a filamentous and much-branched thallus, is known as the mycelium, and the filaments of which the mycelium is made up are called the hyphae. Some of these hyphae penetrate the substratum, serve as anchors for the superficial mycelium and draw nourishment therefrom. The mycelium is normally non-septate and contains abundant granular cytoplasm, numerous minute nuclei and small vacuoles; it is, therefore, a coenocyte. While non-septate condition is characteristic of the young vigorously growing mycelium, cross walls are frequently found in the older hyphae, and the reproductive parts are generally separated from the vegetative ones by septa.

Reproduction

Mucor reproduces both asexually and sexually.

When conditions are favourable, the plant reproduces asexually by the formation of **spores** (or **gonidia**). During the process some aerial hyphae bear at their tips some spherical **sporangia** (or **gonidangia**), and each simple aerial branch bearing a sporangium is called a **sporangiophore** (or **gonidangiophore**). The formation of a sporangium takes place in the following way.

An aerial hypha gradually elongates, and after it has elongated to a certain height, its tip begins to enlarge into a sporangium. Into this enlargement a certain amount of cytoplasm with many nuclei and a considerable amount of reserve food flow from the adjoining region. Then, a dome-shaped area of vacuoles appears within the cytoplasm towards the base of the sporangial wall. This region of cytoplasm is known as the **columellaplasm,** which is surrounded by a peripheral layer of nucleated cytoplasm, known as the **sporeplasm.** The vacuoles then flatten, fuse end to end into one continuous cavity, around which gradually a wall is laid down

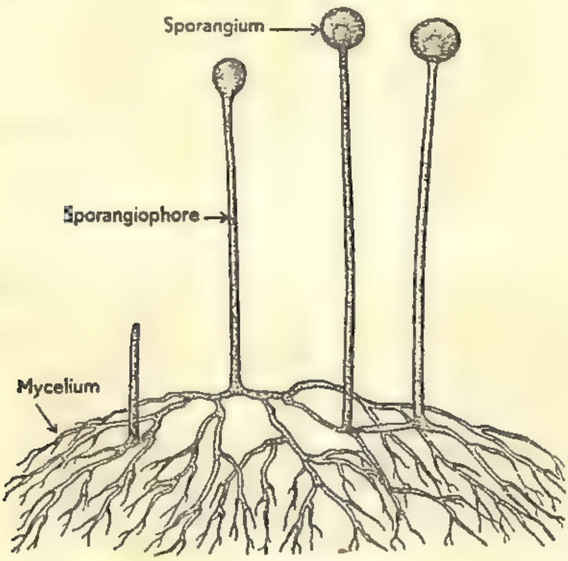


Fig. 147. *Mucor.*
Mycelium and sporangiophores bearing sporangia.

forming the so-called **columella.** Then, there follows a progressive cleavage of the sporangial cytoplasm from the periphery to the centre and *vice versa,* with the result that the cytoplasm becomes gradually cut off into smaller and smaller polyhedral blocks, eventually resulting into small multinucleate or rarely uninucleate units. These ultimate units take on a definite wall and become the **spores** without any further nuclear division. When mature, the spores are thin-walled and ovate in shape, hyaline or dully coloured in mass. The wall breaks up and ultimately disappears on coming in contact

with water. In some species, where the sporangial wall is thin, a liquid droplet appears at the junction of the sporangiophore and sporangium on one side. This droplet then gradually increases in size and envelops the entire sporangium. After some time, the sporangial wall disintigrates, and the droplet forms a conspicuous **sporangial drop** holding the spores in suspension. The sporangiophore on losing turgidity then collapses, usually brings the drop

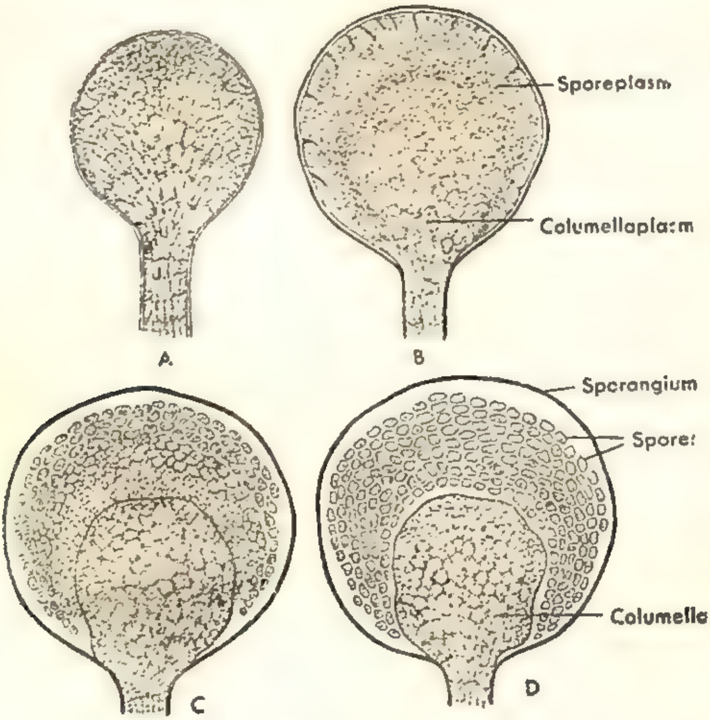


Fig. 148. *Mucor.*
A—D, Successive stages in the development of sporangium, columella and spores (as seen in longitudinal section).

against a solid surface, and it spreads out rapidly owing to surface tension. Ultimately on drying, the spore masses remain firmly adherent together with mucilage, which, however, is readily dissolved and the spores are later on separated in water. Each spore, under favourable conditions, puts forth one or more germ tubes, which ultimately ramifying develop into a new mycelium.

Under certain conditions, especially when the food supply of

the mycelium is exhausted, the plant reproduces sexually and the organs of sexual reproduction are formed. The reproduction is isogamous, which consists in the conjugation of two like gametes. During the process, two club-shaped hyphae (**progametangia**) of different sexes* (**plus** and **minus strains**) approach, come in contact end on end with each other, and a conjugate cell is cut off at the apex of each progametangium by the formation

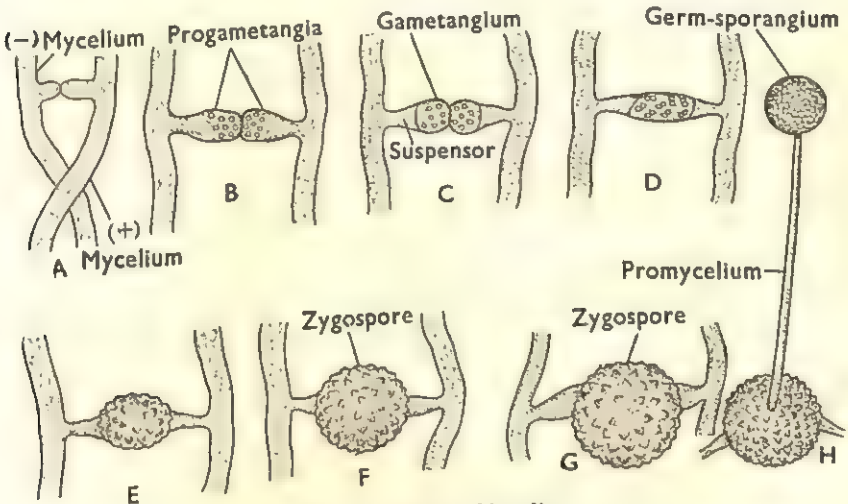


Fig. 149. *Mucor hiemalis.*
A—B, Contact of (+) and (−) mycelia and formation of progametangia; C, Progametangia divided to form gametangia and suspensors; D, Conjugation; E—G, Formation and development of zygospore; H, Germination of zygospore and formation of germ sporangium.

of a transverse wall. The two conjugating cells are the two **gametangia,** and their undifferentiated protoplasmic contents form the **gametes.** The remainder of the special branch bearing a gametangium is known as a **suspensor.** The walls between the gametangia generally break down, the two multinucleate gametes thereupon coalesce, cytoplasm with cytoplasm but the nuclei fuse in pairs and a **zygospore** is formed. Those nuclei which do not fuse ultimately degenerate. The resulting zygospore increases in

*In 1904 Blakeslee demonstrated the presence of two sexually different strains in *Mucor* which he termed as (+) or female, and (−) or male. Zygospore-formation is only possible by the union of these two sexually different strains of mycelia. Although the mycelia are morphologically similar, the *plus* or *minus* strains are physiologically different.

size and forms a heavy, dark and often spiny or otherwise roughened wall. After a considerable period of rest, the zygospore increases in size and then germinates, its outer wall (**exospore**) bursts and the inner wall (**endospore**) puts forth a long germ tube, known as **promycelium,** which ultimately becomes terminated by a **germ sporangium.** Each of the spores contained therein, on being set free germinates under suitable conditions, puts forth a germ tube, which ultimately ramifying produces a new mycelium. It is to be noted that reduction division of the diploid nuclei only occurs in the germ sporangium, and since *Mucor* is heterothallic, the separation of the sexes (+ and −) occurs probably in the formation of sporangia, that is, the spores of one sporangium are either all + or all −.

The gametes may develop without conjugation into a kind of spore known as **azygospore** or **parthenospore.**

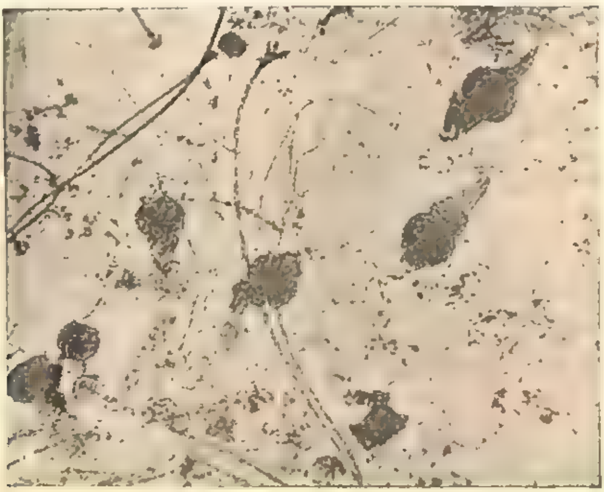


Fig. 150. Photomicrograph showing formation of zygospore in *Mucor*.

Torula state or yeast condition of Mucor

If a portion of the mycelium of *Mucor* be placed in a sugar solution, it becomes divided by transverse walls into thin-walled cells, known as **oidia.** These cells go on budding like the yeast and can excite alcoholic fermentation in the sugar solution producing alcohol and carbon dioxide.

RHIZOPUS

(Fam. MUCORACEAE)

Rhizopus is a large genus containing about 30 species, the best known of which is *R. nigricans*. It is widely distributed as a saprophyte on various substrata. Sometimes it also occurs as a parasite on sweet potato and various fruits causing **soft rots.**

Vegetative body

The aerial multinucleate and coenocytic mycelium consists of rather coarse hyphae and is differentiated into stolons and rhizoids.

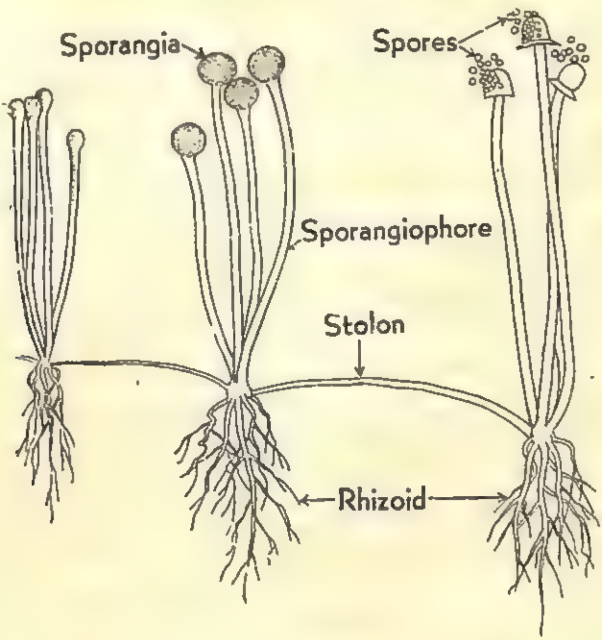


Fig. 151. *Rhizopus*.
Portion of a mycelium showing the vegetative and asexual reproductive structures.

The stolon is an aerial hypha that grows more or less horizontally above the substratum for some distance, and then bends down to the substratum forming a tuft of repeatedly branched, dark-coloured rhizoids. Just exactly opposite the point of origin of the rhizoids, there arise from the stolon a tuft of vertically erect and unbranched

sporangiophores bearing globose sporangia containing dark-coloured spores.

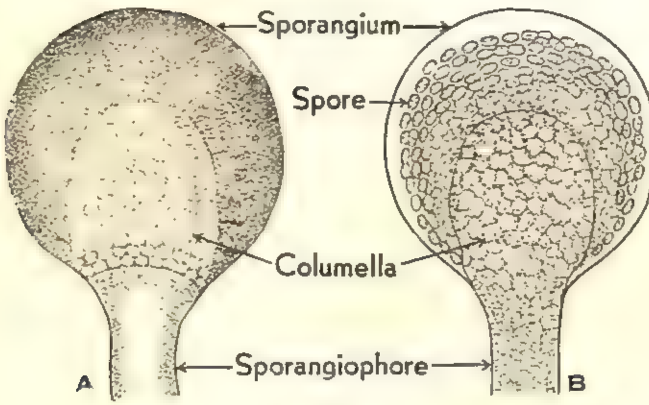


Fig. 152. *Rhizopus.*
A—B, Stages in the development of the sporangium.

Reproduction

Rhizopus nigricans reproduces both asexually and sexually and the

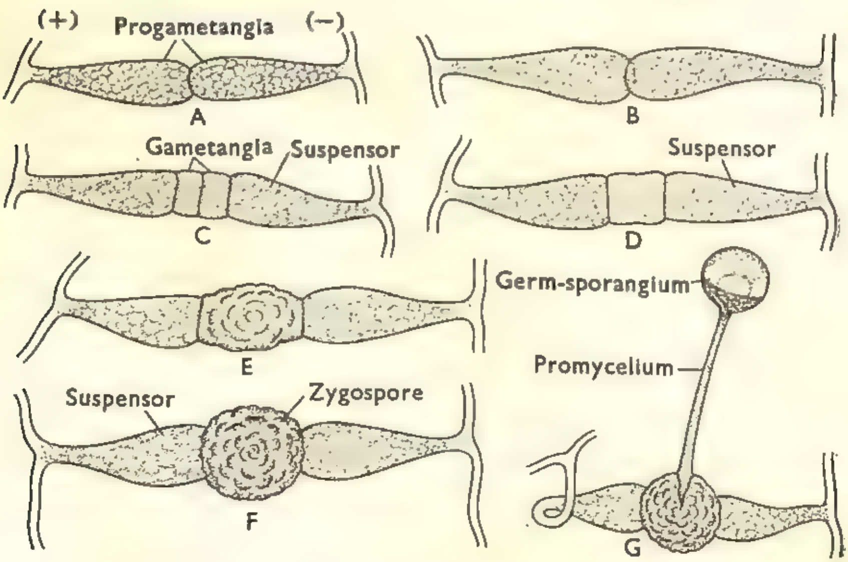


Fig. 153. *Rhizopus.*
A—F, Stages in the formation of zygospore; G, Germination of zygospore.

modes of reproduction agree with those of *Mucor mucedo* in essential details. Furthermore, the fungus is also heterothallic, and the

formation of the zygospore is dependent on hyphae of two different sexes coming in contact with each other.

PILOBOLUS

(Fam. PILOBOLACEAE)

All the species of *Pilobolus* are dung-inhabiting, and of these *P. crystallinus* is commonly found growing as a saprophyte on moist horse dung. It can be readily cultivated in the laboratory by bringing freshly dropped horse dung and enclosing it in a large bell jar lined inside by a sheet of moist blotting paper. Within a couple of days white, cottony growth of the mycelium appears on the surface, and from it characteristic asexual reproductive structures soon make their appearance.

Vegetative body

Like *Mucor mucedo*, its vegetative body is a much-branched coenocytic mycelium consisting of rather coarser white hyphae and containing multinucleate, granulate and vacuolated protoplasm. Some of the hyphae penetrate the substratum and draw nourishment therefrom.

Reproduction

Pilobolus reproduces both asexually and sexually.

Asexual reproduction takes place by means of **sporangiospores.** The modes of development of the sporangia, columella and the formation of spores agree closely with those of *Mucor mucedo*, but the structure of the sporangium represents a special modification of the *Mucor* type. The many-spored sporangium, instead of being spherical, is somewhat flattened and the upper half of the sporangial wall is very much thickened. The columella is rather small and somewhat conical in shape. The part of the sporangiophore just below the sporangium enlarges considerably to form a **sub-sporangial vesicle,** which may be three to four times the diameter of the flattened sporangium. Numerous glistening drops of water appear on the surface of the vesicle and the lower part of the sporangiophore. When the sporangiophore is in a fully

turgid condition, the sub-sporangial vesicle has been found to be sensitive to the directive influence of light. This stimulus causes curvature of the lower part of the sporangiophore, and the sporangium is directed towards the source of light. The neck, *i.e.*, the

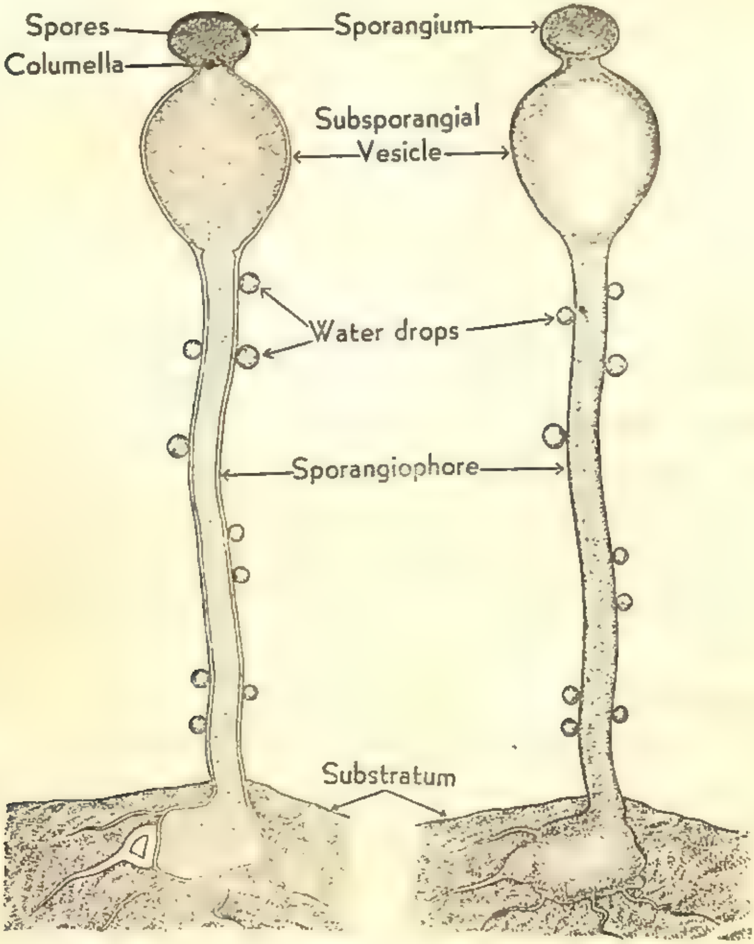


Fig. 154. *Pilobolus.*
General structure of the fungus with the sporangium; the left hand figure denotes an optical longitudinal section of the right hand one.

constricted portion between the sporangium and the sub-sporangial vesicle, undergoes softening and stretching and finally the turgidity of the vesicle reaches to such a degree that the neck ruptures and the entire sporangium, with mature spores, is blown off along

with the watery contents of the vesicle towards the source of light, without much scattering of aim, to a distance of several centimetres. Hence, it is known as the **Pilobolus gun.** The sporangia finally descend on the vegetation, adhere to it and are taken up by animals. The spores, only after passing out of their alimentary canals, are capable of germination and give rise to mycelia of this mould under favourable conditions.

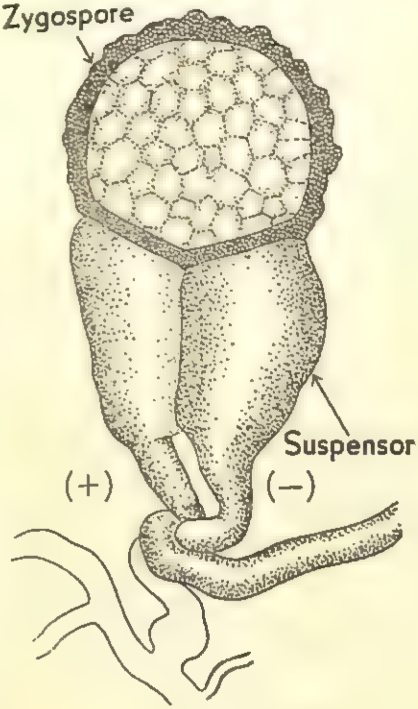


Fig. 155. *Pilobolus*. Formation of zygospore by the heterothallic mycelium.

Sexual reproduction takes place by the union of two isogametangia and their coenocytic contents, and resembles essential features of the sexual reproduction of *Mucor mucedo*. But, in this case, the gametangia are somewhat club-shaped and they meet in such a way that they resemble a pair of tongs. A coenocytic zygospore is formed, by their union, at the point of contact, and it appears as a bud and occupies, as if, a terminal position. *P. crystallinus* is heterothallic, and the formation of a zygospore is dependent upon the union of mycelia of two sexual strains, (+) and (−).

Heterothallism in Mucorales

The species in which conjugation depends on the interaction of two thalli of different sexes are said to be **heterothallic** and the phenomenon is known as **heterothallism.** While those give rise to zygote in mycelium and form a single sporangiospore and therefore consist of one kind of thalli or strains are known as *homothallic* and the phenomenon is known as *homothallism.*

Heterothallism was first discovered by Blakeslee (1904). He found that the zygospore formation in certain Mucorales depends

on the hyphae of two different strains coming into contact. These strains are morphologically similar but physiologically different. These physiologically different strains were termed by Blakeslee as + or − strains, and it is only possible when these two strains come into contact sexual reproduction become possible.

Prior to this work a number of theories were put forward by different mycologists. According to some, zygospore formation depends on the factor, like nature of the medium, humidity of atmosphere and respiration.

In some species, there are visible differences between the two strains, one being more luxuriant in growth than the other. To the relatively well-developed strain the term + was given, to the weaker, — term was applied.

But, as there are some species in which there is one morphological difference in the strains and they are also termed + and −, according to their physiological differences.

Recently Blakeslee and his co-workers have attempted to establish physiological differences between these two strains or sexes along the biochemical lines. Satina and Blakeslee have made chemical tests on the two sexual strains of several species and found different reactions. Blakeslee (1920) and others have observed that the sexual differences show different degrees of intensity. A plant that is very strongly male will conjugate with plants of all degrees of femaleness and *vice versa*. On the contrary, a plant weakly male will not conjugate with one weakly female.

Instances of heterothallism in different species of Mucorales

The different conditions found in Mucorales in connection with heterothallism can be summarized as follows :

(*a*) *Sporodinia grandis*

In this species zygospores are obtained from a single spore-culture and therefore they are homothallic. Zygospore on germination gives rise to the germ sporangium, the spores of which on germination give rise to homothallic mycelium.

(*b*) *Mucor mucedo*

In this species all the spores in the sporangium are of the same strain. The spores from the sporangium on germination produce only one kind of mycelia, either + or — strain, since meiosis takes

place in the zygospore before its germination, there should be two types of nuclei (+ and —) segregating from each zygote nucleus. We would expect, therefore, some of the sporangiospores in the sporangium would contain + nuclei and the rest contain — nuclei, but such is not in this case; one or the other type of nuclei either disintegrate or at any rate do not seem to be included in the sporangiospore. Hence, this species is heterothallic.

(c) *Phycomyces nitens*

In this case, + and — spores as well as fused spores are formed which have not yet been differentiated into + and — and which on germination produce homothallic mycelium. This is explained by the fact that segregation of sexes occur preceding before formation of spores. The sexual character of the homothallic mycelia produced from the undifferentiated spores as unstable and after a few generations, the homothallic condition disappeared.

It is interesting to note that there is apparently no numerical ratio between + and — spores and it sometimes happens that all the spores are of one strain. Sometimes conjugation does not occur in heterothallic forms when the appropriate strains are brought together. Because, poor nutrition and unfavourable temperature may prevent the formation and union of gametangia.

In *Mucor mucedo* and other species, prolonged cultivation under unfavourable conditions may cause the loss of conjugation, so that neutral races are formed, which are unable to respond either to + or — strains.

CLASS II. ASCOMYCETES

The Class Ascomycetes, commonly known as **sac fungi** include such forms as the 'brewer's yeasts' (*Saccharomyces*), the black mould (*Aspergillus niger*), the blue moulds of oranges (*Penicillium expansum*), the powdery mildews of cultivated crops (*Erysiphe*), the cup fungi (*Peziza*, *Ascobolus*), the common edible morel (*Morchella*), the ergot (*Claviceps*), and other fungi of considerable economic importance. A great number of them are parasites on higher plants but most of the species are saprophytes.

The Ascomycetes are characterized by the production of specialized asexual reproductive cells, known as **ascospores,** produced (usually eight in number) within a mother-cell, called an **ascus** (spore sac), which are typically club-shaped or cylindrical, but

may also be globose or pyriform in shape. The asci are often arranged side by side in a definite layer forming a **hymenium**, but sometimes they occur singly or are arranged irregularly, so that no definite hymenium is formed. Intermingled with the asci of a well-developed hymenium there also occur sterile haploid branches, usually slightly exceeding the asci in length, known as **paraphyses.** An ascus develops as a dikaryon cell in which the nuclei fuse and then divide reductionally into eight nuclei, which with some adjacent cytoplasm, are cut off by walls (free cell formation) forming ascospores. Among the simpler Ascomycetes, as the yeasts, the entire vegetative body (a cell) is directly transformed into an ascus. In addition to ascospores, multiplication may also take place by means of conidia and chlamydospores.

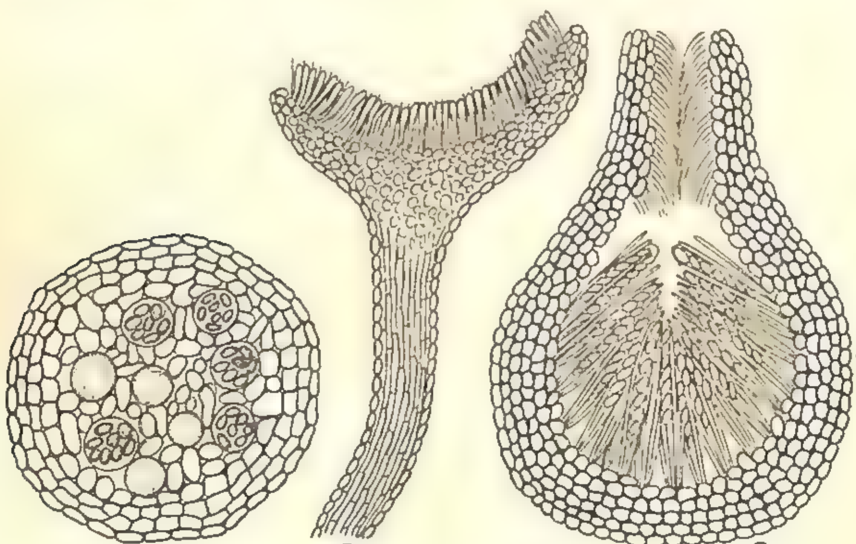


Fig. 156.
A, Cleistothecium ; B, Apothecium ; C, Perithecium.

In most Ascomycetes the asci usually arise in groups and remain protected by a common wall of hyphal tissue, known as the **peridium,** and a definite structure, thus formed, is a fructification, called the **ascocarp.** When young, the ascocarp is somewhat globose in form and remains completely closed. At maturity, it may become flask-shaped in outline opening only by a terminal pore, called the **ostiole;** such a fructification is called a **perithecium.**

In some cases, it opens out to form a cup-shaped or saucer-shaped structure, in the concavity of which the asci are arranged in a hymenium. This type of fructification is known as an **apothecium.** The other two forms are termed as the **perithecium.** On the other hand, a mature ascocarp, if it remains closed throughout, is termed a **cleistothecium.**

Depending on the mode of development of the apothecium, Corner (1929) recognized three types as follows :

(a) **Gymnocarpic.** The hymenium is not enclosed by any hyphal covering from the start of its development.

(b) **Angiocarpic.** From the very start of development the hymenium layer of the apothecium becomes invested by a hyphal covering.

(c) **Hemiangiocarpic.** At first the hymenium begins its development, as in the angiocarpic type, but finally it becomes free by a rupturing of the hyphal covering at the apical region.

Further, those apothecia, in which the asci open by definite apical pores, are known as the **operculate** apothecia, while those in which the asci have no such regular pores but get irregularly ruptured at their tips, are termed as the **inoperculate** apothecia.

The vegetative body of Ascomycetes, with the exception of unicellular yeasts, consists of a mycelium which is much-branched and septate, and contains uninucleate or multinucleate cells. The mycelium usually develops within the substratum, but in a few cases part of it may be superficial. In saprophytic forms it is quite extensive, but in many parasitic forms the mycelium is localized at the region of infection. The parasitic mycelium may be entirely intracellular, or it lives in the intercellular spaces of the host tissue and frequently develops special hyphal branches, which penetrate the living cells and function as absorbing organs, called **haustoria.**

The problem of sexual reproduction in Ascomycetes is very variable and has received considerable attention during recent years. In general, it may be summarized that a gradual decline in sexuality can be traced in the group and the range includes from a well-developed oogamy, in which both antheridia and oogonia are present and functional, to complete suppression of sex organs, although perhaps there always remains a fusion of nuclei at a certain stage in the life cycle, representing the essentials of sexual reproduction. In between these two extremes, there are intermediate forms in which the oogonia are always present but the antheridia are

either absent or when present entirely functionless. The sex organs may be uninucleate or multinucleate.

The Ascomycetes may also be homothallic or heterothallic. In the former case, two mycelia are necessary for sexual union and the formation of ascus and ascospores, while in the latter, only single mycelium is required for the same purpose. In the majority of homothallic species, all the ascospore nuclei of a single ascus are genetically the same, so far as the sex factors are concerned; this phenomenon is referred to as the **primary homothallism.** On the other hand, the ascospores may be genetically dissimilar with respect to the sex factors. Still the mycelia produced from these ascospores will be homothallic, and such a phenomenon is termed as the **secondary homothallism.** Heterothallism also may be of two types: morphological and physiological. In the morphologically heterothallic species, the mycelia belong to two different categories: (*a*) the male mycelium producing antheridia or spermatia, and (*b*) the female one bearing the ascogonia only. A physiologically heterothallic mycelium, however, gives rise to both the male and female elements, but itself suffers from self-sterility. It can, nevertheless, unite sexually with some other compatible mycelia belonging to the same species.

Formation of ascus and ascospores

In the lower Ascomycetes (e.g., *Eremascus*, *Dipodascus*, *Saccharomyces*, etc.) the ascus is developed either directly from a zygote, or parthenogenetically from a gametangium. Usually the two nuclei of opposite sexes fuse inside the young zygote, which is now regarded as the developing ascus. The ascus then enlarges considerably, and the fusion nucleus undergoes reduction division forming usually 4-8 haploid daughter nuclei. From these nuclei, ultimately, 4-8 ascospores are produced.

In the higher Ascomycetes (e.g., *Pyronema*, *Peziza*, *Ascobolus*, etc.), however, the ascogonium never develops directly into an ascus after fertilization. From the ascogonium, on the contrary, one to several unbranched or profusely branched, aseptate or septate, filiform **ascogenous hyphae** are produced. In an ascogenous hypha either all the cells or only a few cells at its apical portion are binucleate, the two nuclei being of different sexualities. Usually, the terminal cell (of the ascogenous hypha) becomes curved like a hook, and is often termed as a **crozier.** The two nuclei in the

crozier divide conjugately, and the daughter nuclei get themselves oriented in such a fashion, that the arch of the crozier receives one pair of them (of opposite sexes), the extreme tip of the crozier having only one, while the other solitary daughter nucleus is situated in the region below the crozier arch. Following this, two partition walls are laid down resulting in the formation of three cells. Of these, the ultimate cell is uninucleate, the penultimate one is binucleate, and the antepenultimate one is also uninucleate. From the binucleate cell, finally an ascus is developed. The two uninucleate ultimate and antepenultimate cells generally unite together to form another binucleate cell. This type of ascus development* is commonly found in *Pyronema confluens*.

The binucleate cell developing into an ascus becomes greatly enlarged and somewhat clavate. Meanwhile, the two nuclei fuse together forming a diploid nucleus. This diploid nucleus then undergoes a complete meiotic division followed by a mitotic one, resulting in the formation of eight haploid nuclei. Nuclear division, as a rule, stops at this stage, but cases of formation of 32-1,024 nuclei have also been recorded. Around each of these eight nuclei, some amount of cytoplasm collects, and finally eight ascospores are delimited. The remaining cytoplasm, which is left inside the ascus, after the formation of ascospores, is known as **epiplasm.**

It was considered previously that the gamete nuclei fused in pairs inside the ascogonium, and consequently, each of the two nuclei in the cells of an ascogenous hypha was diploid. So, when two such nuclei fused in the developing ascus, a tetraploid nucleus was formed. Subsequently, this tetraploid nucleus had to undergo a double reduction in the number of chromosomes in order to give rise to the haploid ascospore nuclei. This phenomenon was known as **brachymeiosis,** and was regarded as a unique feature of the ascomycetous fungi. Recent investigators, however, do not support this idea. They suggest that the gamete nuclei do not fuse, but lie in pairs in very proximity. In this paired condition, the nuclei migrate into the ascogenous hyphae, and the fusion nucleus in the ascus is, therefore, only diploid, and not tetraploid. Consequently, there can be only one reduction in the number of chromosomes.

Besides the normal crozier or hook type, other types of ascus

* Dangeard terms it as the **curvascous type.**

development are also found in the higher Ascomycetes. A brief account of these is given below.

In *Geopyxis catinus* (*Peziza catinus*), the tip cell of an ascogenous hypha is uninucleate just like the ultimate cell of the crozier in *Pyronema confluens*, while the cell behind it is binucleate. This binucleate subterminal cell finally pushes out in a lateral direction and grows out into an ascus.

The next type of ascus development, called the **Plicaria (Galactinia) type,** is exemplified by *Plicaria succosa* (*Galactinia succosa*) and *Acetabula leucomelas* (*Peziza leucomelas*). In this case, a number of cells towards the tip of an ascogenous hypha possess a dikaryon each. The two nuclei in the terminal cell fuse and this cell ultimately develops into an ascus.

In *Pustularia vesiculosa* (*Peziza vesiculosa*) the terminal cell of an ascogenous hypha may form a crozier as in *Pyronema confluens*. The binucleate penultimate cell, however, grows out into another hypha with several binucleate cells, the terminal one of which forms an ascus following the *Plicaria* type of formation.

A fourth type of ascus formation, termed the **rectascous type** by Dangeard, has been found in the lower Plectascales. In this case, the cell is binucleate, as in the Plicaria type. Here, however, a number of asci are formed in a chain lying one behind the other; but this has not been properly examined from cytological standpoint.

In the last type, which can be referred to as the **Laboulbenia type,** true ascogenous hyphae are lacking entirely. Instead, after fertilization, a cell complex appears from the ascogonium, and these cells give rise to asci.

An outline classification of the Ascomycetes (up to Orders) is given in the following table :

Ascomycetes

Plectomycetes	Discomycetes	Pyrenomycetes
(*a*) Plectascales (e.g., *Saccharomyces*, *Eurotium*, *Penicillium*, etc.)	(*a*) Pezizales (e.g., *Pyronema*, *Humaria*, *Peziza*, *Ascobolus*, etc.)	(*a*) Hvpocreales (e.g., *Claviceps*, *Nectria*, etc.)
(*b*) Erysiphales (e.g., *Erysiphe*, *Sphaerotheca*, *Phyllactinia*, etc.)	(*b*) Helvellales (e.g., *Morchella*, *Helvella*, *Geoglossum*, etc.)	*(*b*) Sphaeriales (e.g., *Xylaria*, *Daldinia*, *Chaetomium*, etc.)

* Not treated in this book.

Ascomycetes

- Plectomycetes
  - *(c) Exoascales (e.g., *Exoascus*, *Taphrina*, etc.)
- Discomycetes
  - *(c) Tuberales (e.g., *Tuber*)
  - *(d) Phacidiales (e.g., *Rhytisma*)
  - *(e) Hysteriales (e.g., *Lophodermium*)
- Pyrenomycetes
  - *(c) Dothideales (e.g., *Dothidea*, *Plowrightia*, etc.)
  - *(d) Laboulbeniales (e.g., *Laboulbenia*, *Stigmatomyces*, etc.)

The characters of the *three* main subdivisions are as follows :

(*a*) **Plectomycetes:** Characterized in having a closed ascocarp without any definite opening, a **cleistothecium,** within which the asci either arise from the floor and stand parallel to one another, or they are irregularly arranged; in some cases, a definite fructification is wanting.

(*b*) **Discomycetes:** Characterized in having a well-developed fruit body, an **apothecium,** which becomes more or less cup-shaped at maturity; the asci intermingled with paraphyses stand in parallel series forming a hymenium, which occupies the concavity of the cup.

(*c*) **Pyrenomycetes:** Characterized in having a flask-shaped fructification, the **perithecium,** opening at the top by an ostiole and containing within it asci in parallel series.

ORDER **PLECTASCALES**

Simple types having neither the apothecium nor the perithecium; asci are produced either singly, one from an ascogonium and without any covering, or a number of irregularly placed asci lie within a protective covering of thick-walled hyphae forming the cleistothecium.

SACCHAROMYCES

(Fam. SACCHAROMYCETACEAE)

Saccharomyces, or yeasts, are mostly saprophytes which are widely distributed on substrata containing sugar. They are commonly found on such media as fruits, nectaries of flowers, exudates of

* Not treated in this book.

plant tissues containing sugar, soils of vineyards, etc. Some are distinctly parasitic on plants and animals including man. Some *Saccharomyces* are of economic importance and are largely used in various industries involving fermentation, the most common of which is *S. cerevisiae*. They are also very good sources of vitamin B, and are used in medicines.

Vegetative body

The body of the yeast plant is mostly unicellular, but at the time of vegetative reproduction several cells are found to remain united with one another forming colonies. Certain species, under special conditions of nutrition, may form distinct mycelia which are very unstable, because with slight alteration in the composition of the medium they break up into small cells.

Each cell is rounded or elliptic in form, consisting of a delicate cell wall and containing within it a granulated and vacuolated protoplast with a single nucleus. The chemical nature of the cell wall is obscure. It is neither made up of cellulose nor of chitin. The nucleus is not of the normal type but of a degenerated one, because the nucleolus is found at the periphery of a big central vacuole containing within it the nuclear reticulum only. Hence, the vacuole is not an ordinary sap vacuole, but is a **nuclear vacuole.** Food reserves in the form of glycogen, droplets of oil and refractive granules of volutin are distributed in the cytoplasm.

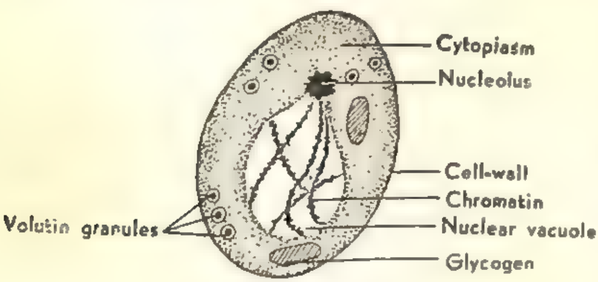


Fig. 157. An yeast cell.
(after Wager.)

Reproduction

Saccharomyces reproduces by vegetative, asexual and sexual methods.

Vegetative reproduction takes place by **budding.** At the time of budding a small outgrowth, a **bud,** is formed at one pole of the mother-cell. The nucleus divides mitotically

into two daughter nuclei. One daughter nucleus, with some amount of cytoplasm, migrates into the bud. A gradual constriction of the plasma membrane, at the point of origin of the bud, leads to the formation of two daughter cells of unequal sizes. The small cell soon enlarges and buds in its turn, before it is detached

Fig. 158. *Saccharomyces.*
a—e, Successive stages in budding and formation of daughter cells.

from the mother-cell. In such cases, the daughter cells of successive divisions remain attached with one another for some time before separation.

Under suitable conditions, the cell contents may round themselves up and form 4 endospores, known as **ascospores,** and the mother-cell is called an **ascus.** These spores are eventually liberated by the rupture of the ascus wall, and under suitable conditions reproduce by the process of budding.

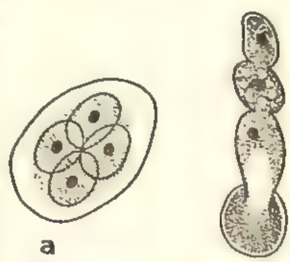


Fig. 159. *Saccharomyces.*
a, Formation of ascospores; b, Germination of an ascospore and formation of new plants by budding.

The species of *Saccharomyces,* until recently, were thought to be wholly parthenogenetic, but researches of Dr. Winge (1935) have shown that it is not so. Sexual reproduction occurs in the genus *Saccharomyces.* In this case, there is conjugation between two vegetative cells. Each of the two conjugating cells produces a short protuberance, and two such protuberances ultimately unite to form a **conjugation tube.** The two nuclei of the two conjugating cells migrate into the conjugation tube, unite with each other and form a diploid nucleus. The conjugation tube then gradually broadens and ultimately forms a more or less dumb-bell-shaped zygote containing the diploid nucleus. Then, there follows

three successive divisions forming eight haploid daughter nuclei, the first division being a reduction division. About each of these nuclei eight **ascospores** are delimited within the mother-cell (zygote), called an **ascus.** At maturity the ascus wall bursts, the ascospores are liberated and these under favourable conditions multiply by budding.

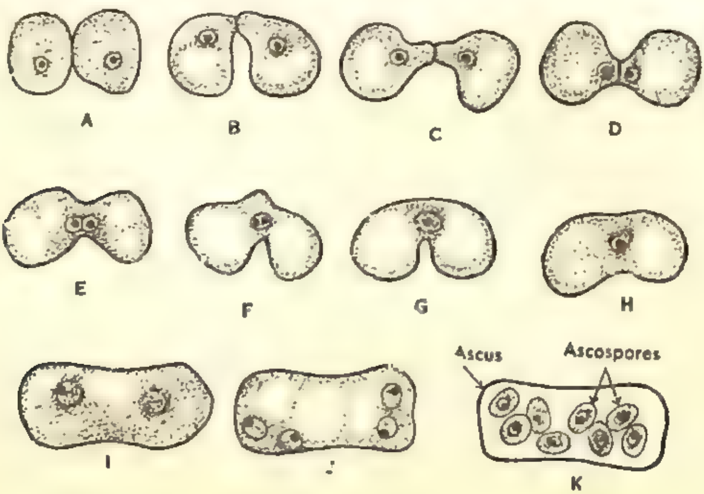


Fig. 160. *Saccharomyces.*
A—H, Successive stages of conjugation; I—K, Stages showing the formation of ascus with ascospores.

Winge has been able to demonstrate conjugation not only between the vegetative cells, but also between the ascospores as given below, which will clearly indicate that there is a definite alternation of generations in the life cycle.

Vegetative cell (2n) ⟶ Ascus (2n) $\xrightarrow[\textit{Division}]{\textit{Reduction}}$ Ascospores (n)

↓

Germination of ascospore (by budding) (n)

↓

Vegetative cells (n) ⟶ Conjugation between 2 such vegetative cells (n+n) $\xrightarrow[\textit{Union}]{\textit{Sexual}}$ Cell zygote (2n)

↑

Vegetative reproduction (by budding of the cell zygote) (2n)

↑ (to Vegetative cell (2n))

A

Vegetative cell (2n) $\longrightarrow$ Ascus (2n) $\xrightarrow[\textit{Division}]{\textit{Reduction}}$ Ascospores (n)

$\uparrow$ $\downarrow$

Vegetative reproduction (by budding) of the spore zygote (2n) $\longleftarrow$ Spore zygote (2n) $\xleftarrow[\textit{Union}]{\textit{Sexual}}$ Conjugation between 2 such ascospores (n+n)

B

Fig. 161. Schematic representations (A & B) of the life cycle of *Saccharomyces* showing alternation of generations.

Alcoholic fermentation

When yeasts grow in sugar solution alcoholic fermentation is set up. Sugar is decomposed by an enzyme (*zymase*) into alcohol and carbon dioxide. The gas is given off in streams of bubbles forming froth, while the alcohol remains in the solution. If the supply of oxygen be in excess, very little alcohol is formed, but when the supply of oxygen is least more alcohol is formed. The chemical change can be represented as follows :

$$C_6H_{12}O_6 + \text{yeasts} \longrightarrow 2C_2H_5OH + 2CO_2$$

EUROTIUM

(Fam. ASPERGILLACEAE)

Most of the species of *Eurotium* are saprophytes and occur on a wide variety of organic substrata. A few species are parasites and cause diseases of the skin, ear and respiratory organs of higher animals including man. They are commonly found as filamentous mouldy growth on the surface of damp fruits and vegetables, preserved fruits, moist breads, jams and various conserves, and also on imperfectly dried herbarium specimens. Many species are commercially important on account of their hydrolysing powers on starch and sugars and cause fermentation to citric and oxalic acids, and rarely to alcohol.

The generic name *Aspergillus* was given to the conidial stage of the fungus long before its ascospores were found, and this name still survives in the name of the family.

Vegetative body

The vegetative body is a much-branched mycelium consisting of usually colourless, septate hyphae. It ramifies in or on the surface of the substratum, or through the intercellular spaces of the host tissue. Each hyphal cell contains granulated, vacuolated and multinucleate protoplasm with oil globules as food reserves.

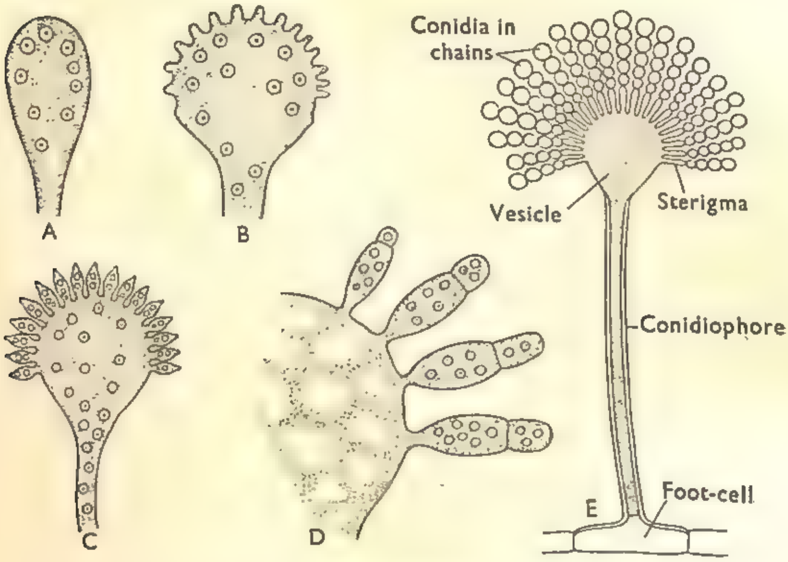


Fig. 162. *Eurotium* (*Aspergillus* stage).
A—D, Successive stages in the development of conidiophore and formation of conidia on sterigmata; E, A conidiophore with sterigmata bearing conidia in chains (sectional).

Reproduction

Eurotium reproduces both asexually and sexually.

During asexual reproduction numerous straight, thick-walled, aseptate and upright hyphae shoot up in the air. These are called **conidiophores.** The free end of each conidiophore swells up and usually becomes spherical forming a vesicle. This vesicle buds out a large number of peg-like outgrowths, called **sterigmata.** From the tip of each sterigma spherical or nearly spherical, smooth or roughened **conidia** are cut off in basepetal succession, *i.e.*, the youngest conidia remain in contact with the sterigmata, while the oldest ones are farthest away from them.

The cytoplasm and nuclei stream up the conidiophore into the sterigmata and finally into the developing conidia. The number of nuclei in each conidium is variable and it varies from species to species. Usually, it is multinucleate, but in some rare cases there may be one nucleus in each conidium. The conidia, as they are formed, are not separated from one another for the time being, but they remain in rows or chains on the sterigmata till they become ripe. They are produced in enormous quantity and at maturity become deciduous, and are readily carried away by the wind. Each conidium, under favourable conditions, germinates on a suitable substratum and produces a mycelium directly. It has already been stated that it is to this conidial stage of the fungus, the generic name *Aspergillus* was given.

Sexual reproduction of *Eurotium* will be described here for the best known species *E. herbariorum* (= *Aspergillus herbariorum*). In the species the same mycelium, producing the conidia, eventually bears the sex organs.

The female branch, or the **archicarp,** is a specialized hypha, which becomes coiled, at first loosely but later on very closely, in a helix. This archicarp, at first one-celled, is soon divided into several multinucleate cells. At this stage, it becomes differentiated into three portions: a multicellular **stalk,** a unicellular **oogonium,** and a terminal unicellular **trichogyne.** It differs from the female sex organs with which we have already become familiar in that it represents only a multinucleate segment of a narrow hypha, and its protoplasm is not rounded off to form an ovum.

After the differentiation of the archicarp, there appears another septate hypha, from the tip of which the unicellular, multinucleate **antheridium** is cut off. The antheridium develops either independently of the archicarp on another hypha, or is formed on slender branches arising from beneath the archicarp. After its formation, the antheridium appears to climb up the side of the coiled archicarp. The union between the antheridium and the archicarp has not been observed in any case and possibly does not take place. The antheridium appears to be rudimentary and its nuclei usually degenerate before it attains the full size. The growth of the antheridium may even be checked, or the antheridium may not develop at all.

However, the oogonium soon becomes septate and forms binucleate cells. From these binucleate cells small outgrowths develop,

which grow and form branched hyphae, the **ascogenous hyphae.** From the terminal or subterminal cell of an ascogenous hypha an

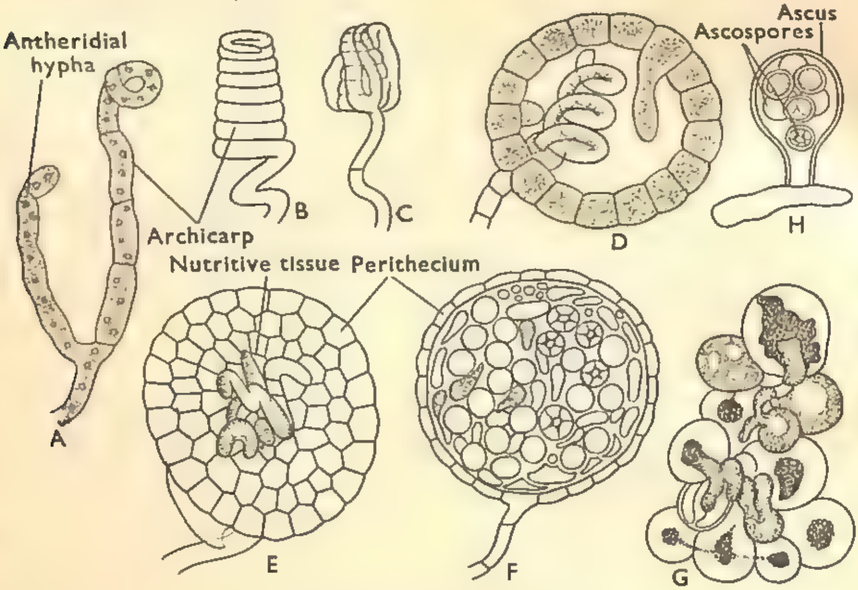


Fig. 163. *Aspergillus herbariorum.*
A—F, Successive stages in the development of a perithecium (cleistothecium); G, Group of young asci; H, A mature ascus with ascospores.

ascus develops. When young, each ascus is binucleate. The two nuclei fuse to form a fusion nucleus. It undergoes three divisions, in one of which reduction in chromosome number takes place, forming eight daughter nuclei, around which **ascospores** are delimited. The cytoplasm, which is not used up in the formation of ascospores, constitutes the **epiplasm** containing food substances, especially glycogen. Each ascospore has a sculptured spore wall (**epispore**) and is of characteristic form, and when seen laterally, somewhat resembles a pulley wheel or a butcher's tray.

A little before the septation of the oogonium some vegetative hyphae grow up and cover the sex organs. The hyphae by interweaving and septation form a thick outer wall of small-celled, pseudoparenchyma which completely encloses the sex organs. Some of the hyphae grow inwards and form a nutritive tissue around

the sex organs. The entire structure, thus formed, is the fructification of *Eurotium* and is termed a **cleistothecium.** The wall of the cleistothecium becomes invested with a brittle yellow substance. At maturity, the ascogenous hyphae, the cells of the nutritive tissue and the walls of the asci disintegrate and are ultimately absorbed, so that the ascospores lie free within the outer brittle pseudoparenchymatous sheath of the cleistothecium. This wall finally decays and the ascospores are set free. Each ascospore, under favourable conditions, germinates on a suitable substratum and produces a new mycelium.

PENICILLIUM

(Fam. ASPERGILLACEAE)

Most of the *Penicillium* are saprophytes that grow on various vegetable and animal substrata, such as decaying vegetables, fruits, meats, etc. A few of them are responsible for the diseases of nose, ear, throat, lungs and other organs of man and animals. Most species cause economic losses, but a few of them are used for industrial purposes, such as those that are involved in ripening cheeses. The wonder drug **penicillin** was first obtained from *P. notatum*, by Sir Alexander Fleming. The structure of the asexual and sexual reproductive organs vary from species to species. *P. vermiculatum* is one of the species whose life history has been fairly worked out and a brief description of the fungus is given in the following paragraphs.

Vegetative body

The mycelium consists of much-branched, septate and anastomosing hyphae that creep over the surface of the substratum and produce very fine rhizoids, which penetrate the substratum and draw nourishment thereform. The hyphal cells are constantly uninucleate. When the fungus grows on potato, the mycelium is at first colourless, then slowly becomes sulphur-yellow and eventually reddish with age.

Reproduction

Penicillium reproduces both asexually and sexually.

Asexual reproduction takes place by means of **conidia,** which are cut off from the apices of the **conidiophores.** Aerial slender branches, consisting of 2-3 cells, grow upwards from the mycelium and form the conidiophores. Each conidiophore produces a whorl of symmetrical branches at its tip, and each of these branches, in its turn, produces a number of closely-packed branches in a whorl. These ultimate branches are known as **sterigmata,** and the branches bearing the sterigmata are called **metulae.** The whole branching system constitutes the **penicillus,** meaning a brush or broom, which is the characteristic of the genus *Penicillium*. Each sterigma is a slender tube, narrowed at its apex to a long acuminate point, from which elliptical, thick-walled, minutely spiny and uninucleate conidia are successively cut off in a chain. The conidia are deciduous and are usually disseminated by the wind. Each conidium, under favourable conditions, puts forth a germ tube, which ramifying produces a new mycelium.

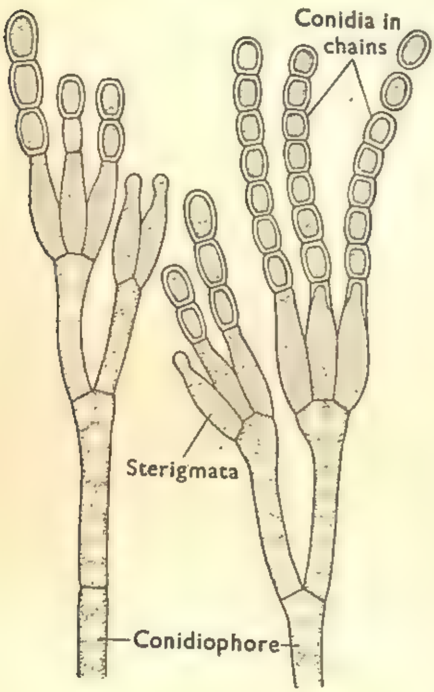


Fig. 164. *Penicillium*. Conidiophores bearing sterigmata and conidia in chains.

Sexual reproduction is oogamous. The **ascogonium** develops from erect unicellular hyphal branches. When young, it is uninucleate. As it elongates, the nucleus divides and re-divides to form 32-64 nuclei, which are distributed in the general mass of the cytoplasm of the ascogonium. Meanwhile, another uninucleate branch develops from a neighbouring hypha and cuts off a uninucleate terminal cell, the **antheridium.** This antheridial branch, during its development, forms several spirals around the ascogonium. The tip of the antheridium becomes applied to the ascogonium, and at the point of their mutual contact a pore is formed by the dissolution of the intervening walls. The actual fusion between

the male and female nuclei has not, however, been observed so far, but owing to the heterothallic nature of the fungus, it can be assumed that gametic union possibly takes place. In any case, the multinucleate ascogonium undergoes septation to form a row of binucleate cells, and from these cells one or more **ascogenous hyphae** of binucleate cells grow out. Meanwhile, sterile entangled vegetative hyphae grow up around the sex organs and form a loosely-felted

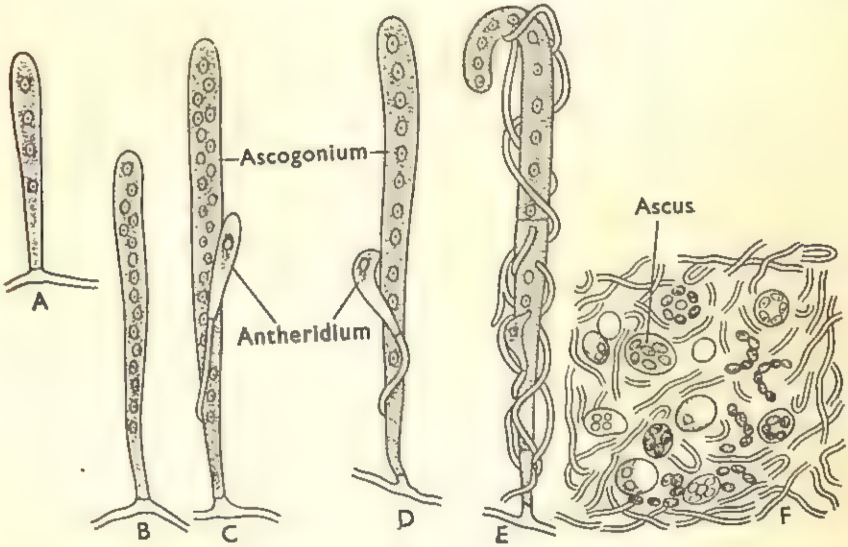


Fig. 165. *Penicillium.*
A—B, Young ascogonia ; C—D, Ascogonium after development of antheridium; E, Ascogonium surrounded with sterile hyphae; F, Part of an ascocarp showing asci, sterile hyphae, etc.

outer region of a mature **ascocarp** (**cleistothecium**). Further details of the ascus development are unknown, but mature asci have been found to lie irregularly distributed within a mature ascocarp. Each **ascus** is somewhat globose in shape and contains 4 to 6 elliptical **ascospores** with minutely spiny outer wall. Since the fungus is heterothallic, the ascospores are of two sexes. On germination, they give rise to different types of mycelia consisting of uninucleate hyphal cells.

ORDER ERYSIPHALES

Superficially growing parasites; aerial mycelia colourless or

dark-coloured; mostly having a solitary layer of asci, arranged parallelly within a cleistothecium having prominent appendages.

ERYSIPHE

(Fam. ERYSIPHACEAE)

Several species or *Erysiphe* cause a type of plant disease, generally known as the **powdery mildew.** They are so called, because the large number of conidia, produced by the causal agent on the surface of the host, appear as white powdery patches. The disease is widely distributed throughout the world. Some of the species cause serious damage to a number of vegetables and ornamental plants. About 10 species have been reported on a wide variety of hosts, of which *Erysiphe polygoni* is described in the following paragraphs. This species is responsible for the disease known as '*powdery mildew of peas*'. Every year, particularly by the end of January or in February, the recognizable symptoms of the powdery mildew appear on the pea plants. At first white powdery spots become visible on the upper surface of the leaves, but gradually these extend to the lower surface as well. Eventually, the leaves turn yellowish and fall off. Sometimes the leaves become reduced in size and the infected pods get dried and shrivelled.

Vegetative body

The mycelium consisting of short uninucleate cells is entirely superficial. It is attached to the leaves and draws nourishment by means of haustorial branches that pierce the walls of the living cells of the host.

Reproduction

Erysiphe polygoni reproduces both asexually and sexually.

At the time of asexual reproduction somatic hyphae produce a large number of erect **conidiophores,** which bear several **conidia** in chains at their tips. The conidia are usually hyaline, elliptical, sometimes barrel-shaped or cylindrical. When these conidia fall on a suitable host, they germinate under favourable conditions and produce mycelia. It has been recorded by Brodie (1945) that a considerable percentage of conidia may germinate in air entirely devoid of moisture.

During sexual reproduction, usually **male** and **female gametangia** come in contact. At first their intervening walls dissolve, and then nuclear migration takes place. There is a considerable difference of opinion regarding the nuclear fusion. Pos-

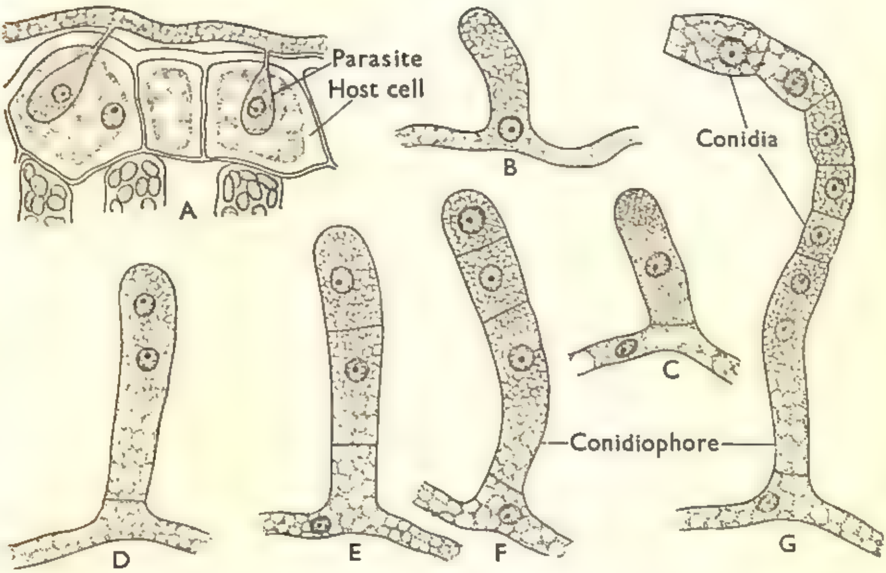


Fig. 166. *Erysiphe.*
A, Parasitic haustoria within epidermal cells of the host; B—G, Stages in the development of conidia on the conidiophore.

sibly after nuclear fusion, the female gametangium, the **oogonium,** elongates and divides to form a row of cells. The penultimate cell of the newly formed row gives rise to **ascogenous hyphae,** from the cells of which **asci** are developed. During the development of asci, the sex organs are surrounded by the nearby hyphae forming the outer layer of the **cleistothecium.** This cleistothecium is spherical to subglobose and composed of polygonal cells. They are covered by long, unbranched, interwoven or free appendages. Generally 2 to 8 asci are found within the cleistothecium. Each ascus is ovate and usually contains 4 **ascospores.** These are hyaline, elliptical and one-celled. When the ascospores mature, they are discharged from the ascus and also from the cleistothecium, fall on the suitable host and germinate under favourable conditions giving rise to new mycelia.

Control measures

The disease may be controlled by treating the seeds with water

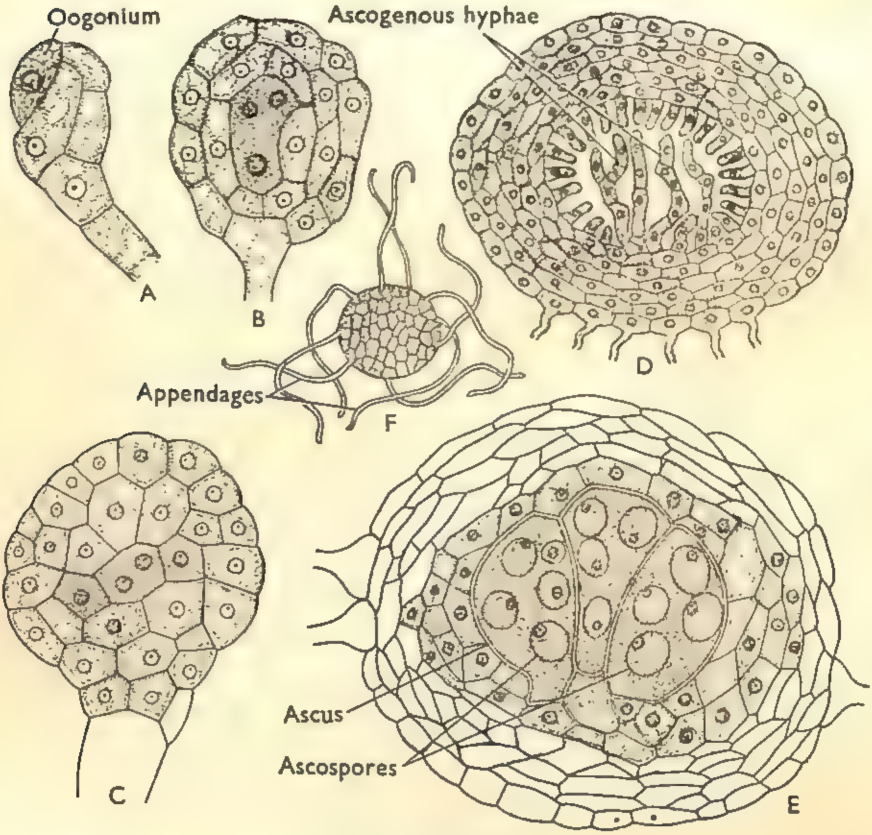


Fig. 167. *Erysiphe.*
A—E, Gradual stages in the formation of sex organs and subsequent development of ascus and ascospores; F, A cleistothecium.

at 50° C. for 10 minutes, or dusting the plants with sulphur as well as selecting the resistant varieties.

SPHAEROTHECA

(Fam. Erysiphaceae)

Sphaerotheca is a common parasitic fungus. It occurs every year during the later part of the winter season in the Indo-Gangetic

plain, while in the hills it grows in summer as well. Some of the species are important from the economic standpoint, as they cause damage to several cultivated crop plants, such as rose, hops, strawberry, gooseberry, raspberry and various cucurbits.

The disease first makes its appearance as patches of white powdery masses on the leaves, stems and sometimes even on the flowers of the host plants. Very quickly these patches extend and completely cover up the surfaces on which they are growing. The popular name of the disease is the **powdery mildew.**

Vegetative body

The vegetative body of the pathogen is a superficial mycelium. The hyphae consist of short, uninucleate cells and are intertwining in nature. At some points on the hyphae are produced short **haustoria,** which enter through the epidermal cells on both the surfaces of the leaves, thereby effecting anchorage for the pathogen as well as helping in the absorption of food from the host tissue.

Reproduction

Sphaerotheca reproduces both asexually as well as sexually.

Within a few days after infection has taken place, some of the hyphae stand vertically erect and behave as **conidiophores.** Each conidiophore now begins to cut off a chain of **conidia** in a basipetal fashion. The conidia are short and elliptic in shape when mature. They are produced in huge quantities and very quickly as well. The conidia are finally detached from the conidiophores and dispersed by the wind. On coming in contact with a suitable host, each one germinates and gives rise to a variable number of germ tubes (from one to three), which then start fresh infections.

When the growing season of the host approaches an end, the production of conidia also gradually stops, and sexual reproduction takes place. The colour of the mycelium changes from white powdery to greyish or greyish-brown. At this stage, two hyphae, lying side by side in close approximation, function as the **antheridial** and the **oogonial branches.** The former is slender, while the latter is somewhat stouter and round. A partition wall is laid down in the antheridial branch, thereby forming a terminal, uninucleate **antheridium** on a uninucleate stalk cell. The oogonial branch may remain unicellular and

uninucleate, or may be divided to give rise to a minute stalk cell and the large, terminal, uninucleate cell, which is the **oogonium** proper or the **ascogonium.** The antheridium comes in contact with the ascogonium, dissolution takes place at the point of contact, and the antheridial nucleus passes down into the ascogonium. According to some workers, like Harpar and others, these two nuclei fuse in the ascogonium, while Claussen, Bergemann and others consider that they do not undergo any fusion within the ascogonium. Subsequent to this, the ascogonium elongates

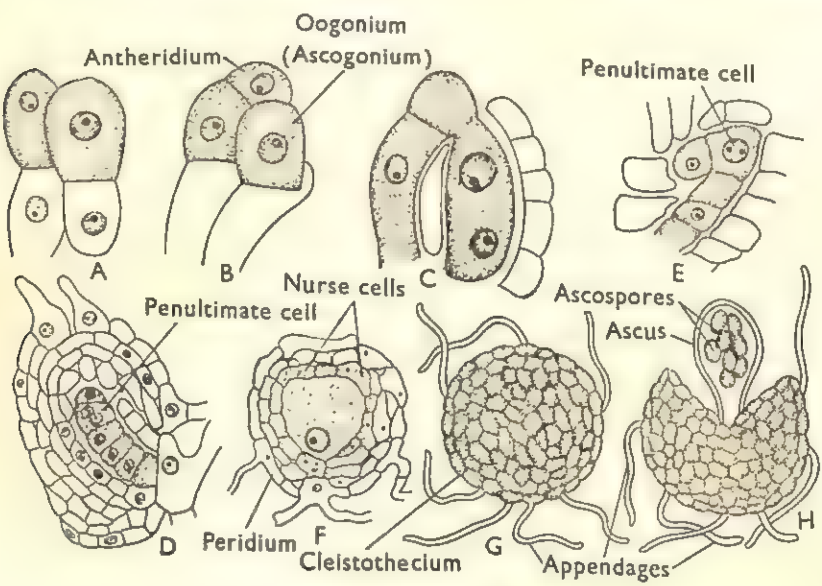


Fig. 168. *Sphaerotheca.*
A—E, Stages in the development of sex organs; F, The young ascus mother-cell surrounded by a layer of 'nurse cells'; G, A mature cleistothecium; H, The same bursting out to liberate the ascus.

and becomes partitioned into three to five cells. Of this row of cells, the penultimate one is binucleate, while the rest are all uninucleate. Inside the penultimate cell the two nuclei undergo fusion, and thus this cell is regarded as the **ascus mother-cell.** The ascus mother-cell enlarges to some extent forming the **ascus,** and by three successive nuclear divisions eight **ascospores** are formed within it. Each ascospore is a haploid body, and on being forcibly liberated from the ascus and coming in contact with a suitable host, germinates and starts the infection afresh.

While the ascus is developing, some of the hyphae from beneath the ascogonium, rapidly grow up and enclose it completely by forming the **peridium.** As a result, a **cleistothecium** is produced. The innermost layer of the peridium, which is two to three layers thick, supplies nourishment to the developing ascus; the cells of this layer are termed the **nurse cells** by Hein (1927). From some of the cells of the outer protective layer of the peridium filamentous myceloid appendages come out. The cleistothecia are minute and round in shape, which are more or less white when young, turning black with age. Each cleistothecium contains a *solitary* ascus. This ascus swells up by absorbing moisture, cracks open the cleistothecium and emerges out. Finally, the tip of the ascus dehisces and the ascospores are liberated.

ORDER **PEZIZALES**

Saprophytes; ascocarp a fleshy or leathery apothecium (usually cup- or saucer-shaped); hymenium totally exposed at maturity; ascus contains usually 8 (sometimes more or less) ascospores, and opening by the shedding of an operculum (lid).

PYRONEMA

(Fam. PYRONEMACEAE)

Pyronema is a saprophytic fungus growing in clusters on decayed leaves in woods or on charred grounds. The short-lived **apothecia** are very minute and orange-coloured. Of the three species occurring under the genus, *P. confluens* is the most well-studied one.

Vegetative body

The vegetative body of the fungus is a mycelium, which is made up of superficially growing, very sparsely branched hyphae. The hyphal cells are rather short and multinucleate.

Reproduction

Pyronema reproduces both asexually and sexually.

During asexual reproduction some of the hyphae from the vegetative body stand erect and cut off chains of **conidia** from their tips. Each conidium is capable of giving rise to a new mycelium on germination.

Pyronema is a homothallic fungus with well-developed sex organs. Though the vegetative hyphae are rarely branched, some of them which bear the sex organs, become forked at one or more points. From these forkings lateral branches develop in upward directions forming tufts. These hyphae then branch repeatedly in a dichotomous fashion, and the ultimate cells of each pair become converted into an **antheridium** or an **ascogonium.**

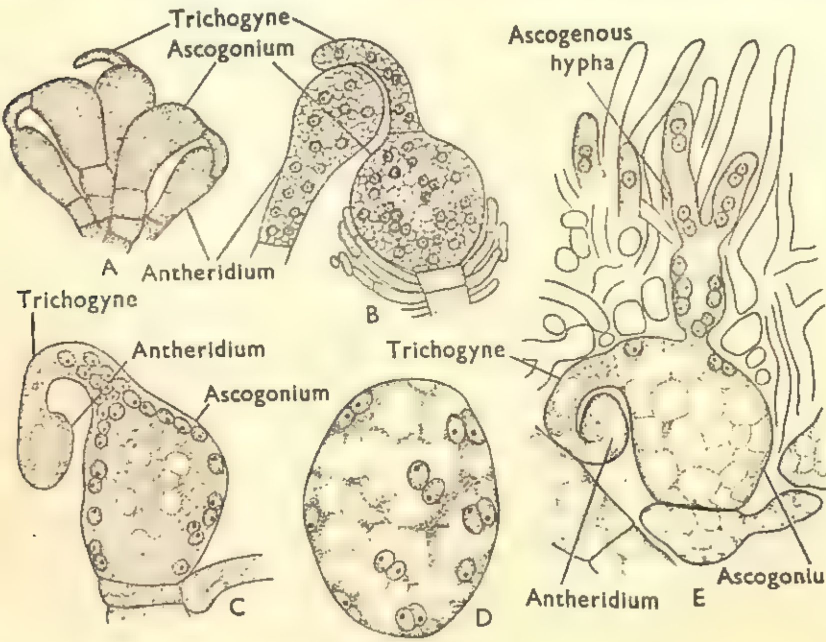


Fig. 169. *Pyronema.*
A—B, Sex organs; C, Union of sex organs and the passage of antheridial nuclei into the ascogonium; D, Union of nuclei inside the ascogonium; E, Dikaryotic ascogenous hypha.

The antheridium is clavate in form and is borne upon one or two stalk cells. The stalk cells are uninucleate, while the antheridium is multinucleate. In the female branch similarly the baloon-shaped swollen, multinucleate ascogonium is borne on one or two stalk cells. From the distal end of the unicellular ascogonium a curved, tubular, unicellular but multinucleate structure, the **trichogyne,** is produced. As the sex organs mature, the nuclei in both the antheridium as well as the ascogonium enlarge in size; those in the trichogyne, however, remain minute and do not increase in size, and finally disintegrate.

The trichogyne comes in contact with the antheridium and dissolution of walls at the point of union takes place. Meanwhile, the nuclei of the trichogyne are degenerated, and the antheridial nuclei with some amount of cytoplasm migrate into the trichogyne. Now the common wall in between the trichogyne and the ascogonium also undergoes disorganization*, and the ascogonial nuclei move towards the centre of the ascogonium. From the trichogyne the antheridial nuclei with the cytoplasm then migrate into the ascogonium and lie in close association with the ascogonial nuclei. Though plasmogamy takes place immediately, the actual fusion of the male and female nuclei in pairs remains a very much debatable point. Some workers consider that karyogamy occurs within the ascogonium, and as a result the nuclei become ultimately diploid, while others are of opinion that the male and female nuclei simply lie in pairs or in small groups in very close proximity but do not fuse. The present-day workers favour the latter view.

Within a few hours of the aforesaid process the ascogonium becomes invested by a **peridium,** which is an envelope formed by the vegetative hyphae originating from the lower cells of the tuft. Simultaneously, a large number of outgrowths appear from the ascogonium, each of which develops into an **ascogenous hypha.**

From the ascogenous hypha the ascus is developed by the usual crozier formation. Lying intermingled with the asci there are unicellular filamentous **paraphyses.** Each ascus contains eight haploid **ascospores.** Each ascospore, on being forcibly liberated from the ascus, forms a new mycelium on germination.

It has already been stated that simultaneously with the development of the asci, the peridium is formed. Within this peridial envelope thus lie the ascogonium, the asci and the paraphyses. The resultant structure is the ascocarp, which is termed here as the **apothecium.** It is to be noted, however, that in *P. confluens* the mature apothecium is in reality a compound apothecium. This is due to the fact that in this species a large number of sex organs are produced very close to one another, and consequently some of the developing fruit bodies fuse among themselves. The apothecium is of the hemiangiocarpic type.

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*According to some workers (Buller, 1933; Wilson, 1952) a pore is formed in the common wall separating the trichogyne from the ascogonium through which the antheridial nuclei migrate downwards. After the migration is over, this pore is blocked by the **pore plug,** a granular body.

HUMARIA

(Fam. Pezizaceae)

Humaria is a common saprophytic fungus. Two species of *Humaria* are usually found, of which *H. granulata* occurs on dungs, and *H. rutilans* on soil or among the mosses.

Vegetative body

The vegetative body is a mycelium. It is made up of branched, septate, multinucleate hyphae.

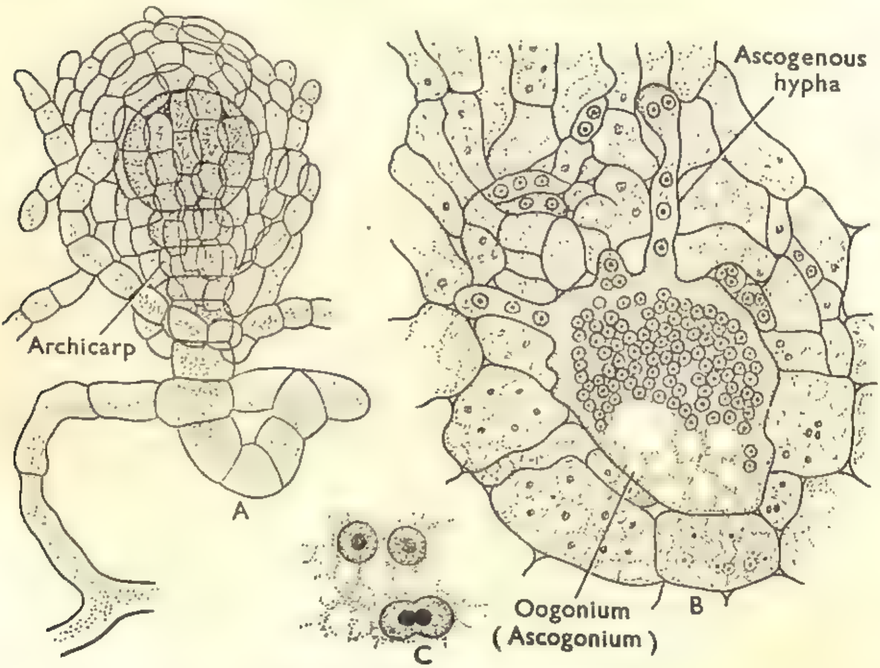

Fig. 170. *Humaria granulata.*
A, A young archicarp; B, An ascogenous hypha being produced from the ascogonium; C, Fusion of nuclei in pairs taking place inside the ascogenous hypha.

Reproduction

Humaria reproduces sexually as well as asexually.

The sexual reproduction in *Humaria* is extremely reduced. In *H. granulata* the antheridium is not at all developed. The **archicarp** arises as a lateral branch from a vegetative hypha. It can be differentiated into a long multicellular stalk and a spherical

or oval, multinucleate **oogonium** (**ascogonium**), but the trichogyne is absent. The nuclei within the ascogonium fuse in pairs, and later on when ascogenous hyphae appear from the ascogonium, they pass into these ascogenous hyphae. During sexual reproduction, a number of vegetative hyphae begin to grow up surrounding the sex organs. These finally intertwine, and after the reproduction, an orange- or dull red-coloured **apothecium** is developed.

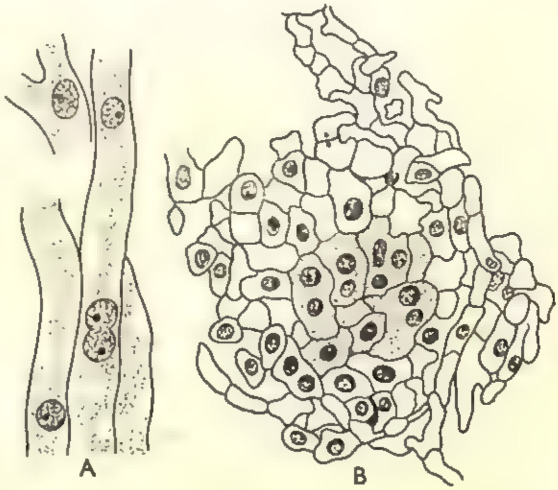

Fig. 171. *Humaria rutilans*.
A, Fusion of nuclei inside the vegetative hypha; B, A very young and developing ascocarp.

In *H. rutilans*, where a greater degree of reduction has taken place, the archicarp even is not produced at all. In this case, the vegetative nuclei of the weft of branched hyphae, uniting to form the apothecium, fuse in pairs, and a true fertilization is lacking.

Asexual reproduction in *Humaria* takes place by means of **ascospores** only. From the ascogenous hyphae the asci are developed. The mature asci, which do not extend beyond the level of the disc, lie intermingled with the paraphyses and contain the haploid ascospores arranged uniseriately. An ascospore, on being liberated, germinates under favourable conditions and forms a new mycelium.

PEZIZA

(Fam. Pezizaceae)

Most species of *Peziza* are saprophytic on ground, on dead wood or on dung.

Vegetative body

The mycelium generally grows in soils rich in organic matter,

or in decaying wood. The mycelial filaments are divided by septa into multinucleate cells and the branching is extensive.

Fig. 172. A few fruit bodies of *Peziza* growing on ground.

Reproduction

Peziza reproduces both asexually and sexually. Excepting the formation of ascospores, asexual reproduction is rare, and takes place by means of conidia.

At the time of sexual reproduction, there arises from the mycelium a conspicuous fruit body known as the **apothecium.** Usually, the apothecium is a fleshy, sessile or sub-sessile cup or saucer-shaped body, regular in form, often brightly coloured, 2 to 40 cm. in diameter and without any hair. A vertical section through the apothecium shows that the upper surface constitutes the **hymenium,** a layer of elongated cells standing at right angles to the surface like a palisade. It consists of **asci** intermingled with supporting and protective filamentous hyphae, the **paraphyses.** Immediately below the hymenium is a layer, thin or fairly thick, the **hypothecium,** consisting mainly of light-coloured hyphae and running parallel to the surface of the hymenium. The basal portion of the cup is known as the **excipulum.**

The sex organs are entirely absent in *Peziza*, but somatic

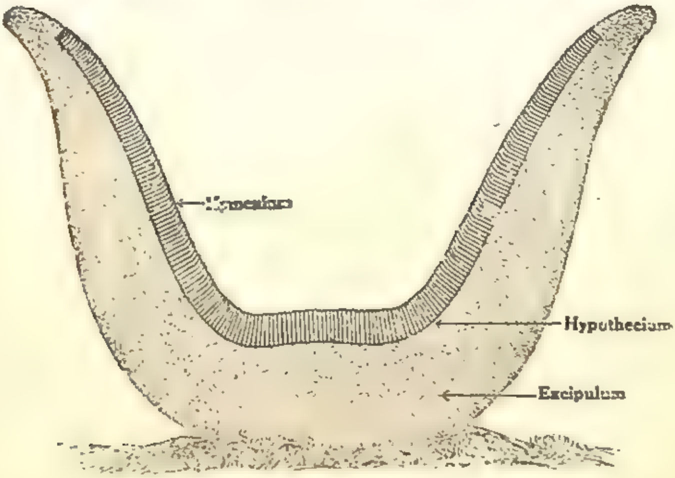

Fig. 173. *Peziza*.
Vertical section through the apothecium.

copulation occurs between certain vegetative cells at the time of reproduction. Consequently, the nucleus of one cell migrates into the other and thus a binucleate cell is formed. Such binucleate cells give rise to a number of **ascogenous hyphae.** The terminal cell of the ascogenous hypha elongates and bends over forming a crozier, and the **ascus** is developed in the usual way. Eight haploid **ascospores** are produced within each ascus. The fully formed ascospores are

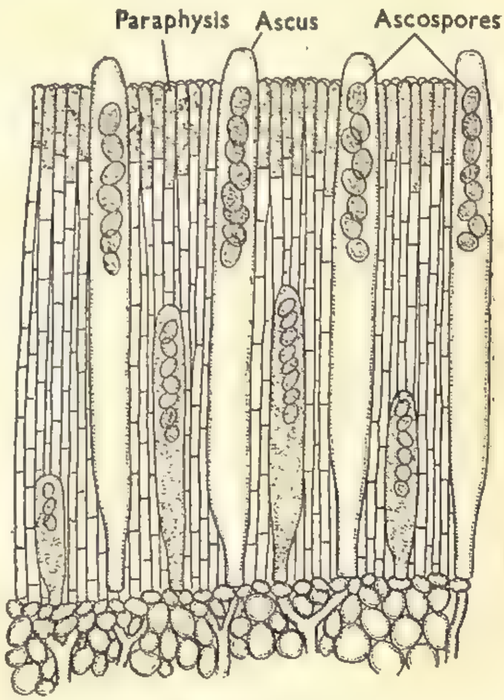

Fig. 174. *Peziza*.
Part of a section through the hymenium showing asci with ascospores and paraphyses.

oval, unicellular and hyaline. When they become mature, each ascus opens explosively by a lid and the spores are shot out in

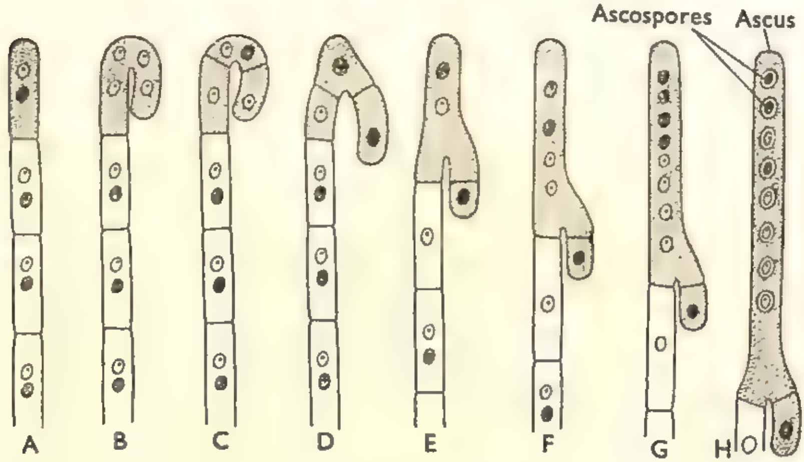

Fig. 175. *Peziza.*
A—H, Successive stages in the development of ascus.

a jet of liquid. Each spore, under favourable conditions, germinates and forms a new mycelium.

ASCOBOLUS

(Fam. Ascobolaceae)

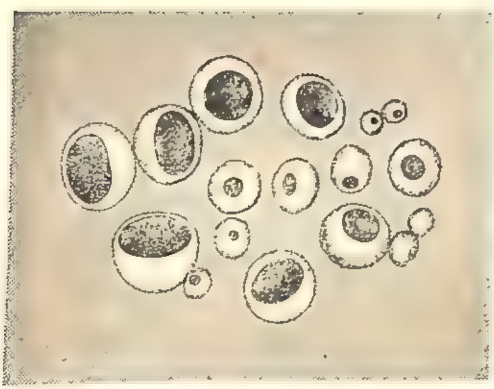

Fig. 176. A few fruit bodies of *Ascobolus* growing on ground.

The members of the genus *Ascobolus* are generally found growing saprophytically on the dung of cows, horses and on the excreta of other animals; sometimes they are also found on the soil rich in organic matters. Of the various species of the genus, the life history of *A. magnificus* is described below.

Vegetative body

The mycelium of the fungus consists of much-branched, septate, hyphal cells with protoplasm, and a considerable amount of oil drops as reserve foods.

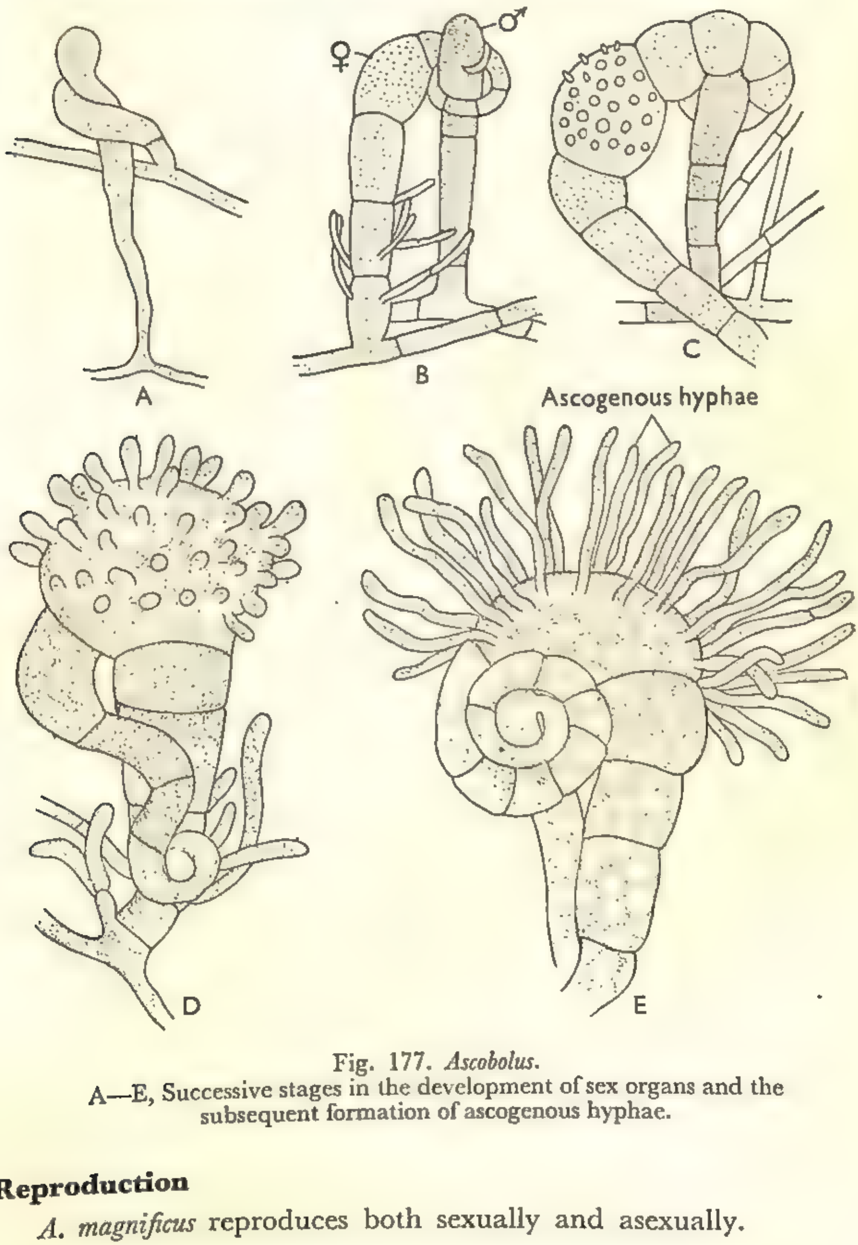

Fig. 177. *Ascobolus*.
A—E, Successive stages in the development of sex organs and the subsequent formation of ascogenous hyphae.

Reproduction

A. magnificus reproduces both sexually and asexually.

Though the fungus is morphologically homothallic and bears both types of sex organs, **antheridia** and **ascogonia,** yet it is self-sterile, because union does not take place between the sex organs of the same mycelium; only the sex organs of two complementary mycelia unite with each other. In this sense, the fungus is physiologically heterothallic and cross-fertile. As a result of this union, the fruit body, the **apothecium,** is formed. The male sex organs, the **antheridia,** and the female sex organs, the **ascogonia,** may develop from the hyphae of both the complementary strains. The antheridium is multinucleate, and more or less clavate or cylindrical in form. The ascogonium, on the other hand, is also multinucleate, and a globose structure with a terminal septate portion, the **trichogyne.** When the antheridium and the ascogonium of the complementary strains meet, the trichogyne first twists round the antheridium, and a passage is established in between the antheridium and the terminal cell of the trichogyne. The male nuclei then travel through the trichogyne, and fuse in pairs with the female nuclei in the ascogonium.

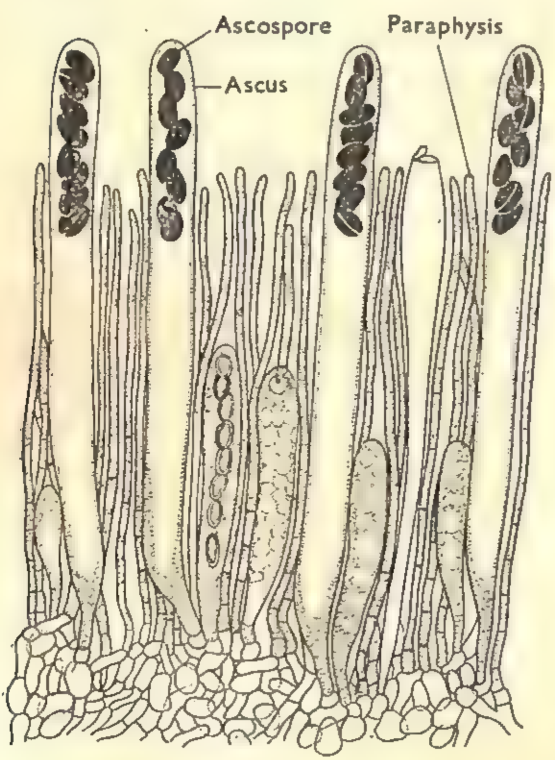

Fig. 178. *Ascobolus*.
Part of a vertical section through the hymenium showing asci with ascospores and paraphyses.

After fertilization, numerous **ascogenous hyphae** begin to develop from the ascogonium, and a number of paired nuclei enter into them. As the ascogenous hyphae elongate, they undergo septation. The **ascus** develops from the binucleate penultimate

cell of each ascogenous hypha by the usual crozier formation method. The eight **ascospores** of each ascus are ultimately discharged, and they germinate under favourable conditions to form new mycelia. During the sexual union, several vegetative hyphae grow up surrounding the sex organs, unite, and there finally arises a fleshy, cup- or saucer-shaped fruit body, known as the **apothecium.** A vertical section through the apothecium shows that the concave surface of the cup is lined by the **hymenium,** consisting of cylindrical asci intermingled with the septate hyphae, the **paraphyses.**

ORDER HELVELLALES

Saprophytes; ascocarps mostly large, fleshy and stalked; hymenium spread over the upper surface, which is often highly convoluted; fertile region distinct from the sterile stalk; ascus opening by an operculum.

MORCHELLA

(Fam. HELVELLACEAE)

Morchella, is an edible fungus, found in various parts of the globe. In India it is commonly found in Kashmeer, the Uttar Pradesh and the Punjab. The fungus is popularly known as the 'morel' and several species are found, of which *M. esculenta* is the most commonly occurring one.

Vegetative body

The vegetative body is a saprophytic mycelium growing in humus soil. The mycelium is extensively branched, and is made up of septate, multinucleate hyphae. After some time the mycelial mat begins to be compacted underneath the soil, and under favourable conditions, a **fruit body** or **ascocarp** is developed above the soil surface.

The ascocarp of *Morchella* is a typical structure, varying from about 2-12 cm. in height. The colour ranges from a dull greyish white to a deep brown, depending on the nature of the specimen as well as the species. It has a thick stalk or **stipe,** bearing a sponge-

like pitted or ridged cap or **pileus,** which is somewhat conical in shape.

A section of the ascocarp shows, under the microscope, that the stipe is composed of a mass of pseudoparenchyma, while the fertile layer, or the **hymenium,** lies lining the pits of the pileus. The hymenium consists of a number of **asci** intermingled with elongated paraphyses. The asci are long, cylindrical, and operculate. Each ascus contains eight large, oval-shaped, and hyaline **ascospores,**

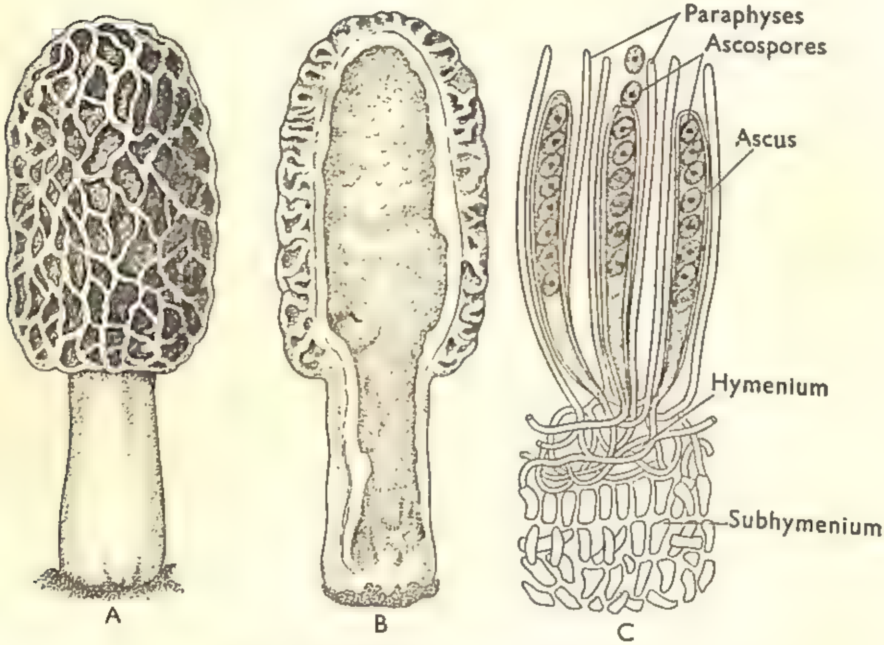

Fig. 179. *Morchella.*
A, A fruit body (ascocarp); B, V.S. of the same; C, Part of a section through the hymenial region.

arranged uniseriately. In between the cells of the stipe and the hymenial layer, just beneath the latter, a group of multinucleate cells occur, constituting the **subhymenium.** Each ascospore, on being liberated and falling on suitable substratum, germinates and gives rise to a new mycelium.

It is of interest to note that so far sex organs have not been recorded in *Morchella.* Diplodization occurs by the fusion of nuclei in the vegetative cells.

ORDER **HYPOCREALES**

Either parasites or saprophytes; mycelium usually forms a stroma (a pseudoparenchymatous mass) in which the asci are formed within perithecia, which lack a peridium.

CLAVICEPS

(Fam. Hypocreaceae)

This genus includes a dozen or more species, of which the best known and almost cosmopolitan one is *Claviceps purpurea*. It is commonly known as the **ergot fungus,** and is a parasite on the ovaries of rye (*Secale cereale*) and on several members of Gramineae. During its development on the host plant the fungus produces dark-coloured, compacted masses of funguous tissue, known as **sclerotia,** in place of the ovaries. The sclerotium is, in reality, called the **ergot.** The sclerotia, when included in the harvested grains, produce a serious disease known as **ergotism,** when these grains are consumed by man or domestic animals. Ergot is well known in medicine for its valuable alkaloid-contents for which it is used in small doses for stopping haemorrhage after child-birth, as well as in larger doses for causing profuse blood discharge.

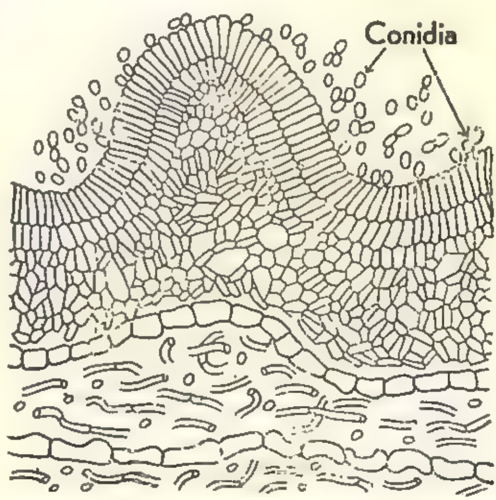

Fig. 180. *Claviceps*.
Formation of conidia showing 'sphacelia stage'.

During the flowering season of the host plants, ascospores, being carried away by the wind, reach the ovaries, ultimately germinate there and bring about infection. The germ tube, produced on germination of an ascospore, penetrates the wall of the ovary, ramifies and produces a much-branched mycelium of septate hyphae within it. Finally, the ovary is destroyed and is replaced by a soft mycelial mass having the same shape of

the ovary. From the surface of this mycelial mass numerous minute, ovoid, uninucleate **conidia** are cut off from the free ends of the hyphae, which constitute the **conidiophores.** This stage of the fungus is known as the **sphacelia stage.** As the conidia are cut off they accumulate in a sweetish liquid excreted from the infected spikelet. This liquid, commonly known as 'honey dew', attracts insects, which carry the conidia with them to other flowers, where they germinate and produce infection. In this way, the disease is disseminated rapidly during the flowering season of the host plants. Eventually, the hyphal mass ceases to form conidia and develops into a densely compacted, hard and dark-brown or bluish-black coloured structure, known as the **sclerotium.** In this way the sphacelial stage is replaced by the **sclerotial stage.** A mature sclerotium is considerably longer and broader than the normal grains of the host plant.

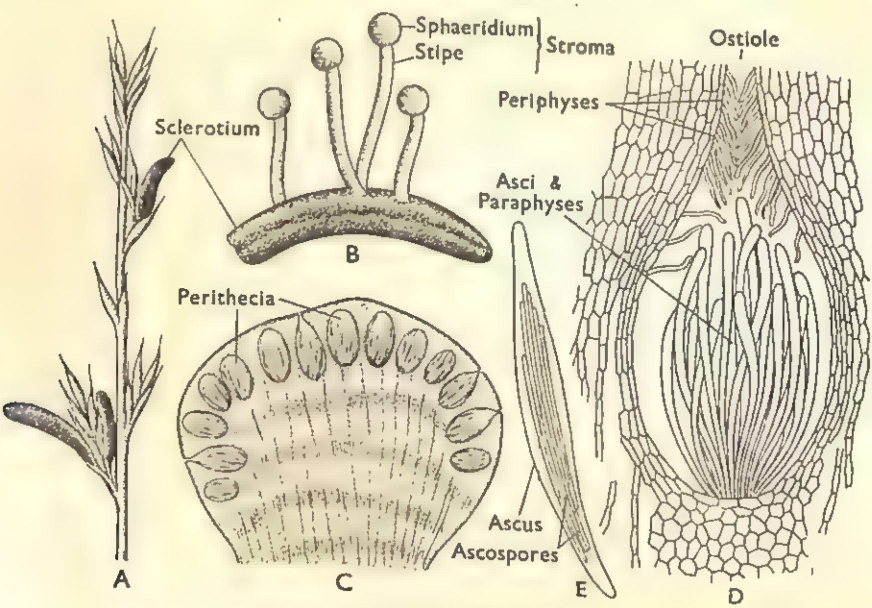

Fig. 181. *Claviceps.*
A, Part of an infected rye plant with sclerotia; B, A germinating sclerotium; C, V. S. through a sphaeridium; D, A perithecium (enlarged); E, An ascus with ascospores.

When the sclerotia ripen, they either fall to the ground and remain there, or become mixed with the grains at the time of harvesting and thrashing. These may return to the field again in the

next growing season of the host plant. The sclerotia are resting bodies and serve as a means of tiding over unfavourable seasons. In the next season, *i.e.*, in the next spring, these sclerotia germinate. Each sclerotium, on germination, produces half a dozen or more small capitate structures, called the **stromata,** constituting the **ascogenous stage** of the fungus. The capitate portion of each stroma, the **sphaeridium,** bears numerous flask-shaped **perithecia.** The perithecia are entirely immersed within the tissue of the stroma. Each perithecium opens at the surface of the capitate portion of the stroma by means of a pore called the **ostiole.** Within the basal portion of the perithecium there are numerous elongated **asci,** each containing eight needle-shaped **ascospores.** The ascospores are forcibly discharged from the ascus, come out through the ostioles and are carried away by the wind. As this happens during the flowering season of the host plant, the ascospores on reaching the spikelets bring about new infection and in this way the life cycle of the fungus is completed.

So far very little is known about the development and formation of the sex organs and also of the ascogenous hyphae. During the formation of a perithecium coenocytic antheridium and oogonium have been reported to be developed from a common hyphal branch and undergone fusion. Migration of nuclei has been observed from the tip towards the base of the ascogonium, after which the tip degenerates and disappears. However, there appears a series of binucleate cells of unknown origin in place of the ascogonium. These binucleate cells form ascogenous hyphae, which in their turn form asci, by the crozier method as described previously.

CLASS III. BASIDIOMYCETES

The Class Basidiomycetes includes such forms as the mushrooms, toadstools, bracket fungi and their allies (*Hymenomycetales*), the puff balls, bird's nest fungi and their allies (*Gasteromycetales*), the smuts (*Ustilaginales*), and the rusts (*Uredinales*). The smut and the rust fungi are obligate parasites on higher plants for at least a portion of their life cycle, while others are usually saprophytes.

The Basidiomycetes is a heterogeneous group, but all the members are characterized by the production of specialized, asexual

reproductive units, called the **basidiospores,** which are produced externally on a mother-cell, called the **basidium.** In most cases, the basidium develops directly by the elongation of the terminal cell of a dikaryon hypha (as in *Agaricus*), but it may also develop as a result of germination of a specialized binucleate spore, called **teliospore** (as in smuts and rusts). Usually, the basidia are club-shaped and unicellular, but they vary considerably in structure, some being transversely 4-celled, while others are longitudinally so. The basidia are mostly arranged side by side in a palisade-like layer forming the **hymenium,** which may either be exposed to the external atmosphere, either directly or indirectly (e.g., *Hymenomycetes*), or may form the lining of completely closed chambers (e.g., *Gasteromycetes*). The hymenia are produced upon or within fructifications, which usually attain great complexity in structure, form and size. These are the familiar structures which are ordinarily referred to as 'the fungus,' but are in reality fruit bodies only, the vegetative body or the mycelium producing these fructifications remaining hidden within the substratum. The basidiospores are typically borne on horn-like projections, the **sterigmata,** developed usually from the top of the basidium. The spores, produced from the basidium, are generally 4 in number, but sometimes may be 2, 6 or more. A basidiospore is always unicellular and uninucleate, thin-walled or thick-walled, and may be hyaline or coloured. Besides basidiospores, conidia and chlamydospores are formed in some species, but they play minor parts in reproduction.

The basidiospore, on germination, usually produces an extensive, much-branched, septate mycelium which may be **primary** (**monokaryon**) or **secondary** (**dikaryon**). The primary mycelium consists of uninucleate hyphal cells and represents the haplophase, whereas the secondary mycelium with constantly binucleate cells represents the diplophase in the entire life cycle. The diplophase ends with the basidial development, and the formation of basidiospores marks the beginning of the haplophase. These two phases are either represented in different mycelia or combined in the same mycelium.

Formation of basidium and basidiospores

Excepting the rusts and the smuts, the basidia are generally developed from the terminal cell of a diplophasic secondary mycelium. Such a developing basidium does not only bear two nuclei

of opposite sexuality, but also is characterized in the majority of the species by the presence of a clamp-connexion at its base.

Clamp-connexions indicate the dikaryotic nature of the mycelium. It is generally formed during the division of binucleate cells. When the dikaryon is ready to divide, a lateral outgrowth is first formed between the two nuclei, and begins to form a curve. The

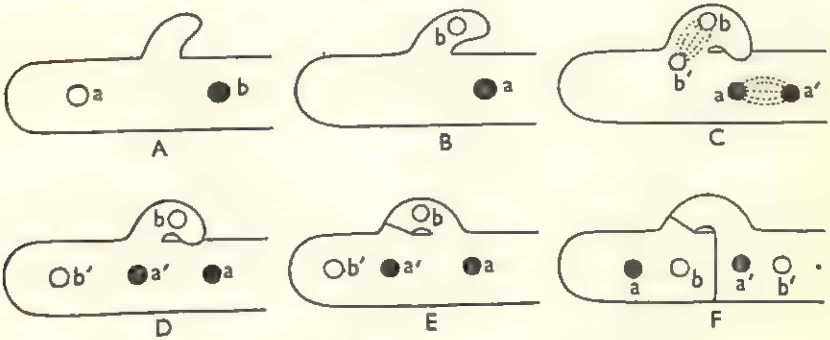

Fig. 182.
A—F, Successive stages in the formation of clamp-connexion.

nuclei divide conjugately, and the lower nucleus of the upper pair passes into the curve. This curved outgrowth, the **clamp,** with a single nucleus is cut off from the main cell by a septum, and at the same time another septum is also formed between the two nuclei of the lower pair. Subsequently, the outgrowth fuses with the lower cell and its nucleus passes into the latter. This curved outgrowth, which acts as a by-pass, is known as the **clamp-connexion.**

The basidium gradually increases in size, becomes more or less clavate, and the two nuclei within it undergo fusion. The fusion nucleus then migrates towards the basidium apex, where it divides meiotically forming four haploid nuclei. Subsequently, four slender projections, the **sterigmata,** are developed at the apical region of the basidium. The tip of each sterigma becomes somewhat swollen, into which a nucleus passes out of the basidium. By the formation of a partition wall at the base of the swelling, a **basidiospore** is now formed. Each basidiospore is more or less uniform and is provided with a small, eccentrically placed, spine-like projection at its basal end, where it remains attached with the sterigma; this projection is called the **hilum.** Of the four

basidiospores thus produced, two are of one sex and the other two of another.

Sexuality in Basidiomycetes

In the life history of a large number of basidiomycetous fungi two distinct sexual phases have been noted, one of which is the **monokaryotic** or **primary mycelium,** the other being the **dikaryotic** or **secondary mycelium.** The process by means of which a monokaryotic mycelium is converted into a dikaryotic one, is known as **diplodization** or **dikaryotization** and the mycelium is said to be **diplodized.** The diplodization may take place in different ways, as follows :

(*a*) An oidium of one sexual phase can diplodize a monokaryotic mycelium of suitable opposite sexuality.

(*b*) Two monokaryotic hyphae of opposite sexualities may unite and produce a dikaryotic hypha.

(*c*) An oidium, produced by a monokaryotic hypha, develops into a new typical hypha representing the parent one, which can either diplodize or itself becomes diplodized on coming in contact with another monokaryotic hypha of opposite sexual phase.

Besides these usual processes of diplodization, a monokaryotic mycelium may become diplodized by a dikaryotic one. This was first discovered by Prof. Buller and is referred to as the **Buller phenomenon** in his honour. In this case, at the time of diplodization one nucleus from a binucleate cell of the dikaryotic mycelium passes into a cell of the monokaryotic mycelium. This introduced nucleus then divides mitotically and one of the daughter nuclei passes through a pore in the septum into the adjoining cell, thus making it also binucleate. This daughter nucleus, in its turn, again undergoes another mitotic division, and the process is continued until all the cells of the monokaryotic mycelium possess two nuclei each. If the sex factors present in the original nucleus of the cell in the monokaryotic mycelium do not become by any means duplicated by the sex factors present in the introduced (*i.e.*, the dikaryotizing) nucleus, it is said to be a case of **legitimate combination;** such a combination gives rise to a dikaryotic mycelium which is capable of producing basidia and basidiospores. On the other hand, if any of these sex factors be duplicated, it is called an **illegitimate combination,** and the dikaryotic mycelium pro-

duced as a result of this can never give rise to basidia or basidiospores.

A basidium of the higher Basidiomycetes gives rise to 4 basidiospores. Each of these spores on germination produces a primary mycelium. It has been observed that in about 90 per cent of the species studied, the primary mycelia are heterothallic, while the same in the rest are homothallic. The heterothallic species, in their turn, fall under two categories : **bipolar species** and **tetrapolar species.**

In bipolar species, the nucleus in each cell of a primary mycelium bears a single sex factor, which is directly opposite in nature (allelomorphic) to that present in the nucleus of a cell of another compatible primary mycelium. These sex factors are borne on homologous chromosomes, and are usually designated as A and B. As a result of diplodization a secondary mycelium is produced, each of whose cells contains two nuclei, one bearing A factor and the other B factor. During the formation of the basidium from such a mycelium, karyogamy takes place in the young basidium resulting in the formation of a diploid nucleus having a factor content AB. At the time of basidiospore formation, this fusion nucleus undergoes meiotic division, and of the four spores produced two bear the factor A, and the other two, the factor B. Each one of the primary mycelia developed from the spores containing the factor A is compatible with either of the mycelia containing the factor B or *vice-versa.*

On the other hand, two alleolomorphic sex factors, borne on separate pairs of chromosomes are responsible for making a species tetrapolar. In such cases, if the sex factors in the nucleus of a cell of a primary mycelium be designated by the factors A and B, then those in the nucleus of its compatible partner are usually referred to as a and b factors. As in the case of the bipolar species, the fusion nucleus in a young basidium has the factor content AaBb. This fusion nucleus then undergoes two successive meiotic divisions to give rise to the four basidiospore nuclei. If both the chromosome pairs bearing the different sex factors in the fusion nucleus undergo disjunction in the first meiotic division, the two daughter nuclei produced may bear Ab and aB factors or AB and ab factors, as the chances permit. When they divide subsequently meiotically, the chromosomes split up this time and four

nuclei are thereby produced; two each of these will, therefore, contain the factors Ab and aB or AB and ab, respectively. If both the chromosome pairs do not undergo any disjunction until the second meiotic division, the two daughter nuclei, produced after the first division, will each have the factor content AaBb as the parent one. When disjunction takes place subsequently, two conditions may happen: the four resultant nuclei may all be different, or for each of the two nuclei the factor contents will be Ab and aB or AB and ab as before. On the other hand, if disjunction takes place in one chromosome pair at the first meiotic division and in another pair at the second one, the four resultant nuclei will be all different bearing the factor contents Ab, aB, AB and ab. In cases where each of the two basidiospores bear the sex factors Ab and aB or AB and ab, the primary mycelia produced from them, behave in the same fashion as in the case of a bipolar species. But, when all the four spores are different, the species exhibits a rigid tetrapolar sexuality.

It has already been stated that all the heterothallic species exhibit either a bipolar or a tetrapolar sexuality. It is interesting, however, to note that in a number of cases a primary mycelium developed from a basidiospore, borne on the basidium of a fructification, is compatible with all the four primary mycelia developed from the basidiospores produced by a basidium of another fructification of the same species. Such fructifications were thought to be of different **geographical races,** as this phenomenon of such complete inter-fertility was first recorded in fructifications collected from widely separated regions on the globe. But, it has now been established that these so-called 'races' may occur not only in quite nearby localities but also on the same lump of dung, log of wood or similar other substrata. The cause of this may be attributed to the presence of multiple allelomorphs in the sex factors of the primary mycelia.

There is never any development of typical sex organs in Basidiomycetes, but nevertheless, a change in the nuclear condition from the haplophase to the diplophase takes place in the life cycle, as stated before, and the mycelium may exist in two or more sexually different strains. In such cases, any cell of a mycelium of one sexual phase may unite with any cell of the mycelium of opposite sexual phase, as a result of which a sporophytic or diplophasic mycelium is produced.

Classification

An outline classification of the Basidiomycetes (upto the Order) is given in the following table:

Basidiomycetes

Hemibasidiomycetes	Protobasidiomycetes	Autobasidiomycetes
Ustilaginales (e.g., *Ustilago*, *Tilletia*, etc.)	(*a*) Uredinales (e.g., *Puccinia*, *Melampsora*, *Phragmidium*, *Cronartium*, *Gymnosporangium*, etc.)	(*a*) Hymenomycetales (e.g., *Stereum*, *Clavaria*, *Hydnum*, *Polyporus*, *Agaricus*, etc.)
	*(*b*) Auriculariales (e.g., *Auricularia*)	(*b*) Gasteromycetales (e.g., *Phallus*, *Lycoperdon*, *Cyathus*, etc.)
	*(*c*) Tremellales (e.g., *Tremella*, *Guepinia*, etc.)	

The characters of the *three* main subdivisions are as follows.

(*a*) **Hemibasidiomycetes:**—Characterized by the fact that more than 4 basidiospores are produced on the basidium, which is either aseptate or divided transversely into 4 cells.

(*b*) **Protobasidiomycetes:**—Characterized by the production of regularly septate (transverse, longitudinal or oblique) basidium, which always bears a definite number of basidiospores, usually 4.

(*c*) **Autobasidiomycetes:**—Characterized by having unicellular basidium, which produces a definite number of basidiospores, usually 4 but may be 2, 6 or more; basidia are always arranged in a hymenium, which may either be exposed to the external atmosphere directly or indirectly (*Hymenomycetes*), or may form the lining of completely closed chambers (*Gasteromycetes*).

ORDER USTILAGINALES

Obligate parasites causing diseases of different crop plants mainly; chlamydospores (teleutospores) produced from intercalary binucleate cells of a mycelium give rise to the aseptate or transversely septate epibasidium.

* Not treated in this book.

USTILAGO

(Fam. USTILAGINACEAE)

The species of *Ustilago*, commonly known as 'smut fungi', belong to a group of obligate parasitic basidiomycetes, which are responsible for the **smut diseases.** They are so called because of their black soot-like spore-masses formed externally on the host plant. The spores are known as **smut spores** (also **chlamydospores, brand spores, resting spores** or **teleutospores**). A mature chlamydospore contains a single diploid nucleus and is surrounded by a thin endospore and a thick, smooth or sculptured exospore. Smut spores are formed, either as separate individual units, or in compacted aggregations of several spores, giving rise to the **spore balls.** At maturity, these smut spore-masses either break up into fine dust-like powder and are readily carried away by the wind (**loose smut**), or they remain firm, compacted together and more or less covered (**covered** or **kernel smut**).

Smut fungi are of considerable economic importance, since they attack most of our cultivated cereals and a few wild and cultivated grasses. The most affected parts of plants are the grains or the entire inflorescences, thus reducing the yield of the cereal grains by 25 to 50 per cent. Most species of *Ustilago* grow parasitically upon a selective host species.

Smuts of our cultivated crops may be grouped into three kinds, on the basis of the time of germination of the smut spores and also the type of infection as follows: (a) **shoot infection** or **general infection type,** *e.g.*, corn smut (*Ustilago maydis* = *U. zeae*), (b) **blossom infection type**, *e.g.*, loose smut of wheat (*U. tritici*), and (c) **seedling infection type**, *e.g.*, loose smut of oat (*U. avenae*).

Corn smut (*Ustilago maydis* = *U. zeae*)

The corn smut infects the Indian corn plant during its growing period. Usually, the ears and the tassels of the plant are attacked, but sometimes various other aerial parts, such as stems, leaves or aerial roots, are also infected. The infection is localized and does not pervade the whole system of the plant. The chalmydospores, formed during the last growing season of the host plant usually lie dormant on the dried stems, in the soil or in other favourable places. With the advent of the spring or the following summer

they germinate in abundance. Each chalmydospore containing a diploid nucleus, on germination, produces a small tubular out-

Fig. 183. Smutted inflorescences of wheat (A—B), and of oat (C—D). A—B, *Ustilago tritici;* C—D, *Ustilago avenae.*

growth, called the **epibasidium.** Its nucleus divides reductionally into four haploid nuclei, all of which either remain within the

elongated epibasidium or only three of them migrate into the epibasidium, while the fourth one remains within its old spore wall. The epibasidium is then divided by transverse walls into four uninucleate cells. The nucleus of each cell divides into two daughter nuclei, of which one migrates into a basidiospore, which buds off from any point on the cell wall, and the other remains within the mother-cell. This process may be repeated so that a few more basidiospores may be produced from a single cell. The corn smut

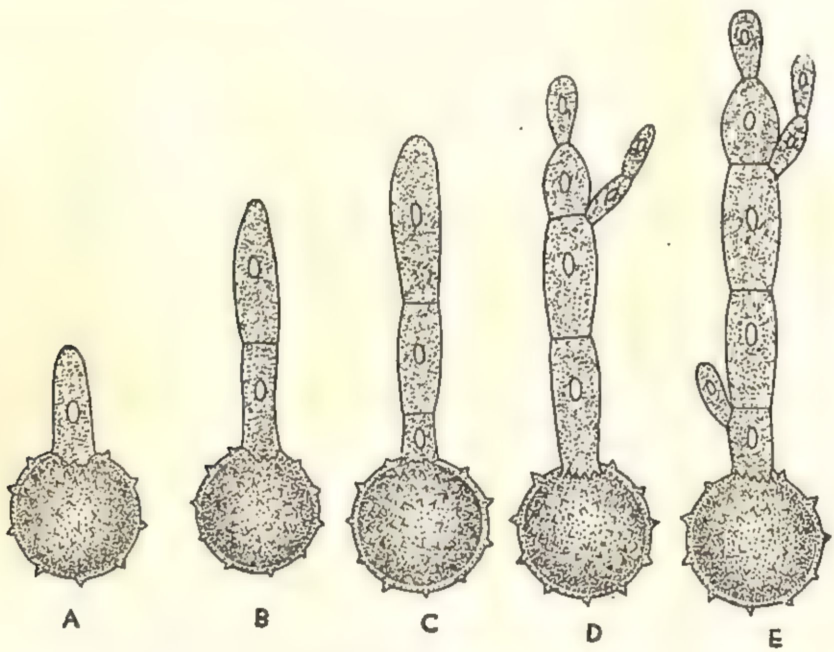

Fig. 184. *Ustilago zeae.*
A—E, Germinating chlamydospores showing the stages in the formation of basidia and the production of conidia by the budding of the basidiospores.

is heterothallic, and out of the four cells formed in the epibasidium, two cells contain nuclei of one sex and the other two of opposite sex. Thus, the basidiospores derived from these cells are of two sexes. Each basidiospore, before or after detachment from the epibasidium, may sometimes bud off conidia of the same sex.

The **basidiospores** or **conidia** are disseminated by the wind, and when they reach the host plant, bring about infection. Typical infection is only possible if the host plant is infected with the

basidiospores or the conidia of both sexes. A basidiospore or conidium germinates on any part of the host plant and sends out a **germ tube,** which soon penetrates the epidermis of the host, enters the intercellular spaces and grows more or less horizontally, forming a haplophasic (monokaryon) mycelium of a few uninucleate cells. Soon union follows between cells of two haplophasic mycelia of opposite sexes. In some cases this union may take place early, just after the penetration of the germ tubes resulting from the basidiospores or conidia of opposite sexes. During union, a cell of a haplophasic mycelium of one sex fuses with a cell of a haplophasic mycelium of opposite sex and the nucleus of one is introduced into the other, and a binucleate condition (diplophasic or dikaryon) is established. This cell, usually a terminal one, now elongates, its two unfused nuclei divide simultaneously forming four daughter nuclei and a cross wall is formed containing a pair of nuclei of opposite sexes. The process is repeated several times, as a result of which a considerable amount of diplophasic (dikaryon) mycelium is formed, which ramifies through the intercellular spaces of the host tissues. It draws nourishment from the living cells by means of short hyphal branches, the **haustoria,** which penetrate them.

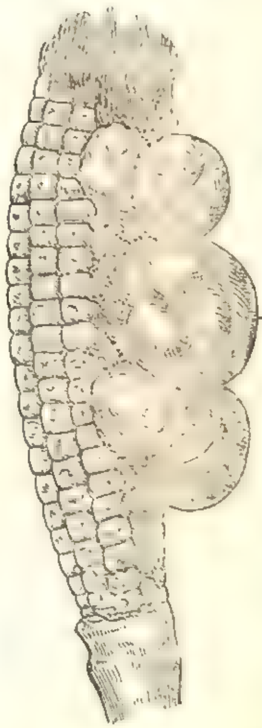

Fig. 185. *Ustilago zeae.* An ear of corn infected with corn smut forming galls.

During the period of vegetative activity of the diplophasic mycelium, the cells of the localized regions begin to divide and re-divide actively due to stimulation caused by the presence of the parasite. As a result, the infected region swells up to an enormous size forming **galls** or **tumours.** Ultimately, the cells of the galls below the epidermis are killed and the diplophasic mycelium begins to form the chlamydospores. Details of chlamydospore formation are not known with certainty. However, when first

formed, they are binucleate, and as they attain maturity the two nuclei of each chlamydospore fuse to form a diploid nucleus, and its protoplast becomes surrounded by a thick wall. At this stage the gall consists of the epidermis surrounding the masses of chlamydospores, a few sterile hyphae, and the remains of the host cells. Ultimately, the epidermis ruptures and the powdery mass of chlamydospores are blown away by the wind. The chlamydospores are resting spores and usually do not germinate until the following spring or early summer, the growing season of the host plant.

Loose smut of wheat (*Ustilago tritici*)

Loose smut of wheat infects the healthy wheat plants at the time of flowering. Just when the wheat plants head out, the

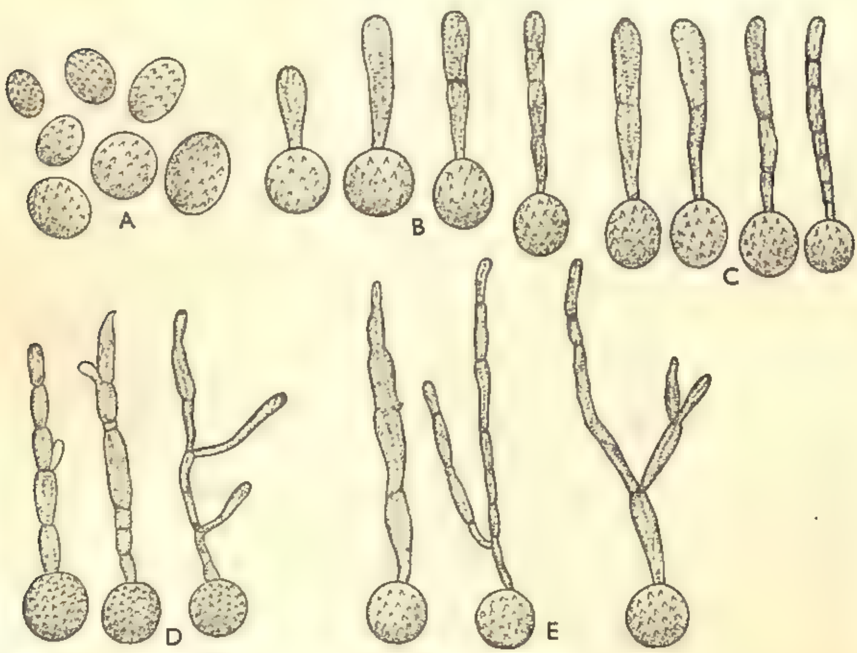

Fig. 186. *Ustilago tritici.*
A, Chlamydospores; B—E, Various stages of germination of chlamydospores in water.

chlamydospores of *U. tritici* are blown about by the wind and numerous spores are lodged between the glumes, where they germinate on reaching the feathery stigmas. Each spore, on germina-

tion, produces a germ tube, which grows down the style and enters the ovary. It then pierces the integuments of the ovule, passes through the nucellus, endosperm and scutellum, and finally enters the axis of the embryo. Here, the fungus continues to grow within the embryo without doing any injury to it, and as the seed matures, it passes into the stage of dormancy along with the seed. These seeds, though infected with the fungal mycelium, appear perfectly healthy. In the following spring, when these seeds are planted, the internal dormant mycelium resumes its activity and grows as an internal parasite keeping pace with the growth of the developing seedling. When the plant attains maturity and at the time of flowering, the fungus makes a vigorous development and destroys the spikelets of the flowering heads, which are finally transformed into black powdery masses of chlamydospores. In most cases, the spikelets are completely destroyed, and when the chlamydospores are blown about by the wind or washed away by rain, only the bare structure of the central axis of the head is left behind. The disease is systemic and not localized as in the case of corn smut, since the mycelium pervades the whole system of the plant body.

Loose smut of oat (*Ustilago avenae*)

The infection of an oat plant chiefly takes place in very young seedlings. The **chlamydospores,** produced on the smutted inflorescences of oat plants, are usually lodged on the surface of healthy grains. These spores can retain their vitality at least for a year. In the next season when these smutted grains are planted, they germinate and the chlamydospores also resume their activity. Each spore on germination produces a **basidium,** which bears the **basidiospores** of two sexes in the usual manner. The basidiospores of two sexes, on coming in contact with each other, unite. From this cell so formed, a short hypha develops which immediately infects the very young seedling. The mycelium keeps pace with the growth of the plant and invades the new tissues as they are formed. The infected plant appears to be somewhat stunted, and the effect of this infection is sometimes so serious that the plant never comes to flower. As the plant comes to blooming, the mycelium penetrates the floral parts and for a time becomes more aggressive, and as a result, the neighbouring structures are also affected. The chlamydospores are finally formed by the mycelium essentially in

the same way as in the case of corn smut. The chlamydospores occupy the place of the grains and sometimes also some of the surrounding chaffy structures. These spores are finally liberated and carried away by winds to healthy flowers and may also bring about infection in flowers instead of seedlings. Like the loose smut of wheat the disease is of the systemic type.

Control measures

(*a*) *Corn smut.* Since the infection is localized and restricted to the aerial parts of plants only, spraying of healthy corn plants with Bordeaux mixtures can prevent the spread of the disease. There are also other recommended methods: (1) rotation of crops, *i.e.*, corn plants are not cultivated on the same field for at least three years; (2) destruction of the infected parts, such as inflorescences and the stalks, before the spores are disseminated, and (3) use of manure free from smut spores.

(*b*) *Loose smut of wheat.* Infection due to loose smut can be effectively controlled by treating the infected seeds with hot water in such a way that the internal mycelium is killed without killing the embryo. This is done by immersing the seeds for a period of ten minutes in hot water bath, maintained at a temperature of 125° F. to 129° F. Great care should be taken during treatment, since, any rise of temperature above 131° F. will kill the embryo and a temperature below 125·5° F. will not kill the fungus at all.

(*c*) *Loose smut of oat.* The loss due to this disease is prevented by treating the seeds with fungicides that kill the spores lodged on the surface of the grains without affecting the vitality of the seeds. For this purpose, an equal part of commercial formaldehyde and water when sprayed or sprinkled on oats give effective results.

TILLETIA

(Fam. Tilletiaceae)

There are two species of *Tilletia* which attack wheat in India causing a disease, known as **bunt** or **stinking smut.** It is so called, because the infected heads of wheat emit a strong smell resembling that of decaying fish, and this is given out by the **brand-spores** or **chlamydospores** of the organism. Of the two species,

Tilletia tritici is characterized by having chlamydospores whose epispore is reticulated.

Infection by *T. tritici* takes place by means of binucleate conidia during the seedling stage of the host plant. A germinating **conidium** sends out a hypha, which directly penetrates the host by pushing between the epidermal cells and a much-branched mycelium of dikaryotic cells is produced within the tissue. Certain cells of the dikaryotic mycelium may become multinucleate by subsequent division of the nuclei. At this stage, the seedling does not exhibit any external symptom of the disease. The mycelium develops within the seedling, keeping pace with the development of the host tissue. Subsequently, when the host begins to flower, there is a vigorous development of the mycelium within the floral organs. The infected flowers have abortive stamens and enlarged ovaries, which are about twice the normal size than those in the uninfected ones. At this time, when the normal grains begin to grow on the infected plants, the ovules are destroyed by the mycelium, and from this mycelium binucleate chlamydospores are produced, replacing the ovules within the infected ovary. At maturity, the two nuclei of each chlamydospore fuse to form a single diploid nucleus. The ovary matures just as in the normal grain, but it contains a mass of chlamydospores or **smut balls** in place of the kernel. The wall of the infected grains containing the smut balls remain intact until the following growing season of the host. The wall eventually breaks, and the chlamydospores from the broken infected grains lodge upon normal grains and return to the field at the time of plantation.

Fig. 187. *Tilletia.* An infected inflorescence of wheat.

The chlamydospore, on germination, produces a **promycelium** or **basidium,** into which the fusion nucleus passes and divides meiotically into four haploid nuclei. Subsequent division or divisions of the nuclei increase the number to eight or more. As the basidium elongates, its protoplasm becomes restricted to the growing tip and at its evacuated basal portion a few transverse septa

are laid down in succession. At the apex of the basidium eight, but occasionally a large number of acicular **basidiospores** are budded off and each receives a single nucleus. As the fungus is heterothallic, half of these spores are of one sex and half of the other sex, segregation taking place during meiosis. Short conjugation tubes connect the neighbouring basidiospores in pairs, usually before they are shed, and the nucleus of one passes into the other. In this way the binucleate condition is established.

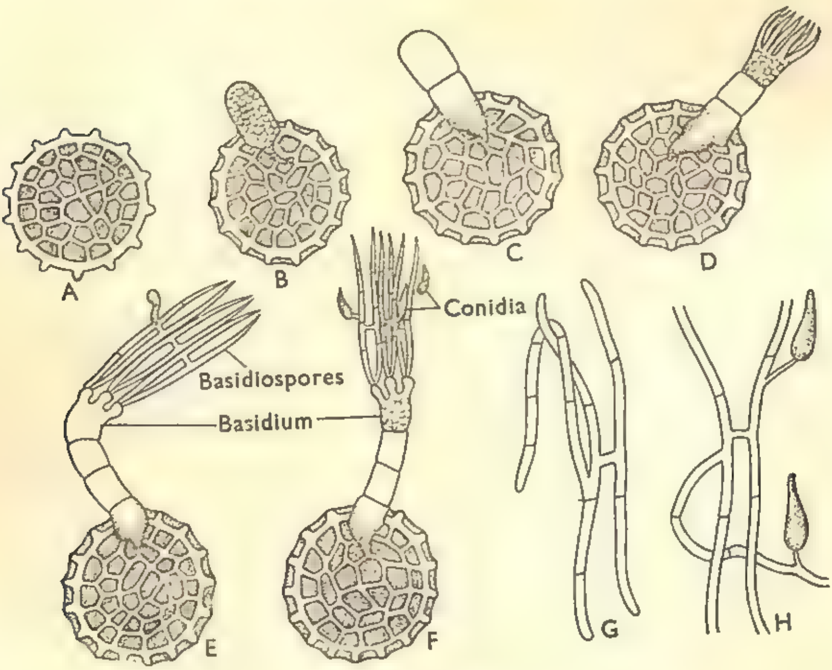

Fig. 188. *Tilletia*.
A, A chlamydospore; B—D, Chlamydospore germinating and forming basidium; E—F, Conjugation of basidiospores and formation of conidia; G, Development of mycelium from a conjugated pair of basidiospores; H, Formation of secondary conidia.

After migration, the basidiospores become septate and under damp conditions, filaments of binucleate cells develop from the segments containing two nuclei. From the binucleate cells of these filaments binucleate sickle-shaped **conidia** are budded off, and from these mycelia of dikaryotic cells may further be produced. When the atmosphere is comparatively dry, similar conidia may be formed

directly from the binucleate segments of the basidiospores while they are still attached to the basidium.

The conidia, whether primary or secondary, are discharged forcibly from the basidium in the same way as that of the basidiospores of *Agaricus*, to be described subsequently, and under favourable conditions they germinate and infect seedlings of the hosts.

ORDER **UREDINALES**

Obligate parasites growing chiefly on angiosperms or gymnosperms and sometimes on ferns; microcyclic or macrocylic, autoecious or heteroecious; basidia transversely septate.

PUCCINIA

(Fam. PUCCINIACEAE)

Puccinia includes a group of parasitic basidiomycetes, which live upon a few ferns but in the main on various species of seed-plants (Gymnosperms and Angiosperms). They are commonly known as **rust fungi** owing to the fact that they cause brown or rusty spots or streaks on living plants, particularly on the leaves. All are obligate parasites and most of them grow on particular host plants or on a small group of closely related hosts. The ravages made by them are well known wherever plants are cultivated, as they cause damage to various cereals worth thousands of rupees every year. They produce at least two distinct types of spores, other have three, four or even five different kinds of spore-forms in a complete life cycle. A rust is said to be **polymorphic,** when several spore-forms occur in its complete life cycle. When a rust produces all the spore-forms in the life cycle on a particular host plant or on closely related hosts, it is called **autoecious.** A large number of species, however, produce their different spore-forms on distantly related hosts, and they are said to be **heteroecious.**

The best-known species of rust fungi is *Puccinia graminis*, commonly known as the **black stem rust of wheat,** which causes greater economic loss and is responsible for one of the most important plant-diseases known. It is polymorphic, since it exhibits a total of five different spore-forms in its complete life cycle, and these are: (*a*) **uredospores** (**urediniospores**), (*b*) **teliospores** (**teleuto-**

spores), (*c*) **basidiospores** (**sporidia**), (*d*) **pycniospores** (**spermatia**), and (*e*) **aeciospores** (**aecidiospores**). Besides the basidiospores and pycniospores which are uninucleate, all other

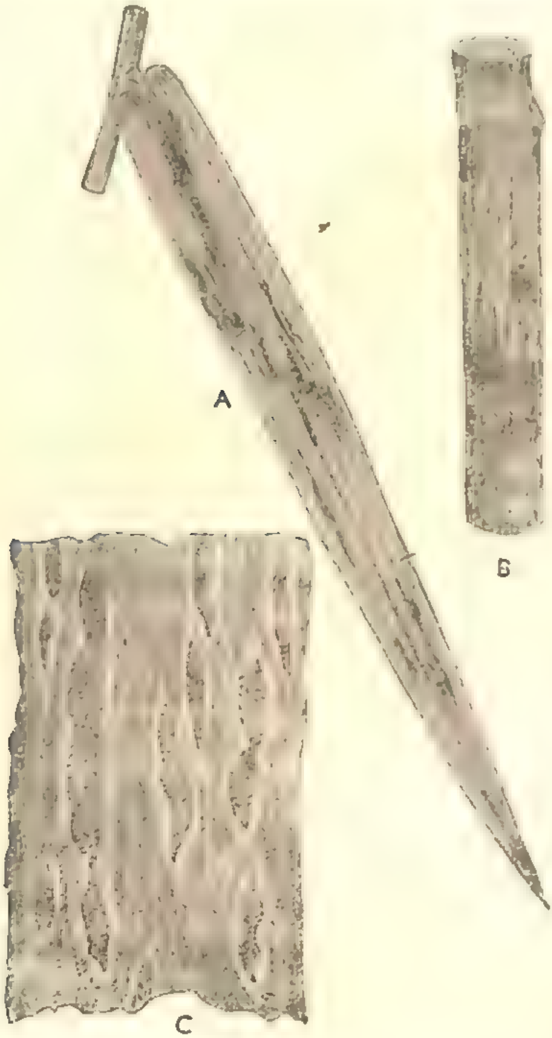

Fig. 189. *Puccinia graminis.*
A—B, Leaf and stem of wheat infected with 'black stem-rust' bearing uredosori and teleutosori respectively; C, Part of the infected stem showing highly magnified teleutosori.

spore-forms are always binucleate. *P. graminis* is, therefore, a **macrocylic rust,** since it produces, besides the teleutospores, two other additional types of binucleate spores. This rust is a heteroe-

cious species producing certain of its spore-forms on wheat plants and others on the leaves of barberry plant. Besides the wheat plant it may also attack oat, rye, barley and many other grasses during the growing season of these plants. Based on this behaviour of the fungus, a large number of strains or physiological races have been established within the species *P. graminis*. These races are sometimes also referred to as subspecies. Of these, the one which infects the wheat plant (*Triticum aestivum* = *T. vulgare*) is known as *P. graminis tritici*.

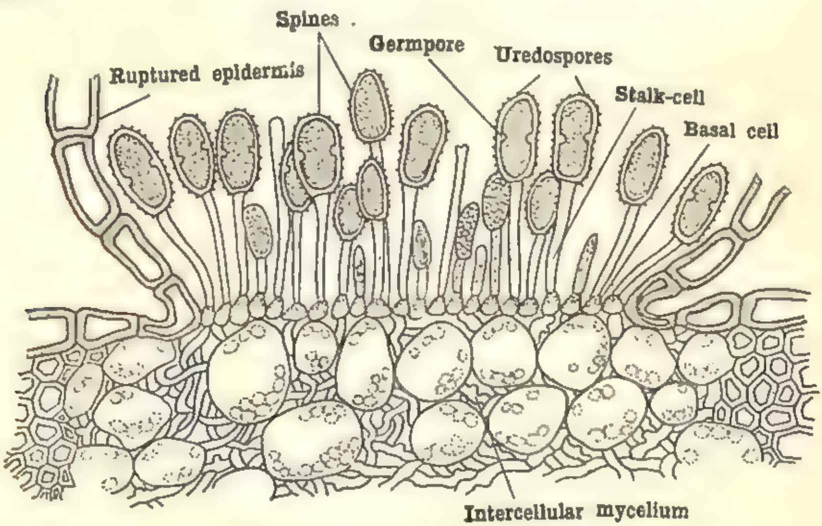

Fig. 190. *Puccinia graminis*.
Section through a uredosorus showing uredospores in various stages of development.

The life history of *P. graminis* can be divided into five different stages as follows:

Uredinial or red rust stage. In late spring there appear, on the stems and leaves of wheat plants, vertically elongated reddish-brown pustules (sori) or blisters called **uredosori (uredinia)**, each of which at maturity contains a powdery mass of innumerable small orange-red spores called **uredospores (urediniospores, or summer spores, or red rust spores)**. A uredospore is somewhat ovoid in form, binucleate, always unicellular, minutely spiny and with a constant number of germ pores. At maturity, the epidermis of the blister ruptures and the uredospores of a uredosorus are freely exposed and disseminated by various means, especially by the wind, to other wheat plants. On reaching a wheat plant,

a uredospore germinates within a few hours by sending out usually a single germ tube, which on reaching a stoma penetrates it, and eventually ramifies through the intercellular spaces of the host tissues forming a dikaryon (diplophasic) mycelium consisting of short binucleate cells. The mycelium derives its nourishment from the neighbouring cells by means of short haustorial hyphal branches. The growth of the mycelium is localized and does not grow deep into the tissues of the host. Beneath the epidermis of the host the hyphal branches become more numerous, and within 5-6 days after infection, begins to form uredosori with uredospores. When very young, a uredosorus consists of a layer of parallel binucleate **basal cells,** which are pressed directly against the inner walls of the epidermis. Each of these cells elongates vertically and divides transversely; the lower daughter cell, thus formed, remains undivided and is called a **foot cell.** The upper daughter cell divides again to form two cells, the terminal one matures into a **uredospore** and the lower one into a **stalk cell.**

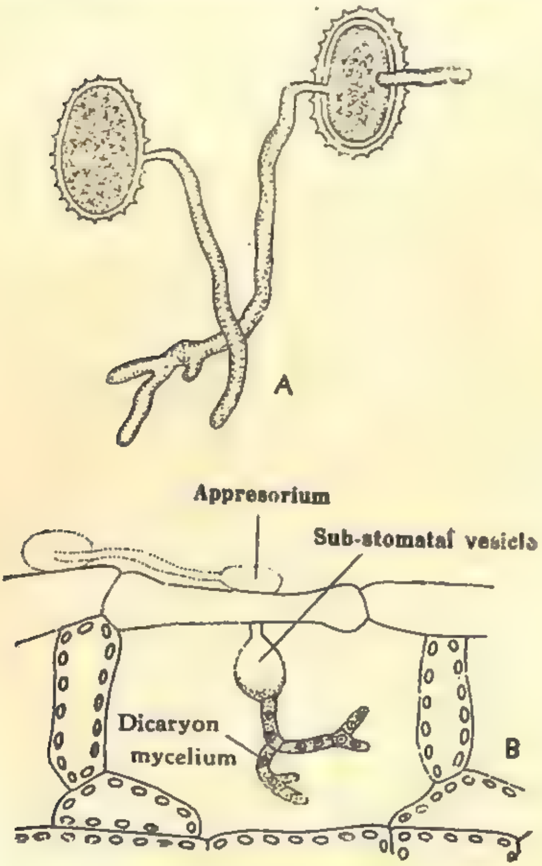

Fig. 191. *Puccinia graminis.*
A, A germinating uredospore; B, Infection of wheat plant by the growth of the infection hypha of a germinating uredospore through a stoma.

Like the cells of the mycelium the foot cell, the stalk cell and the uredospore are all binucleate. The maturation of the uredospores is followed by rupturing of the overlying epidermis of the host plant, resulting in their final dissemination. Other wheat plants

become gradually infected by these uredospores, and within 10-12 days a new crop of uredospores is produced on the newly infected plants, and these may repeat the same stage. It is for this reason the uredospores are often spoken of as **repeating spores.** In this way the uredospores are blown about from one field to a neighbouring one and the disease spreads like a wild fire wthin a very short time.

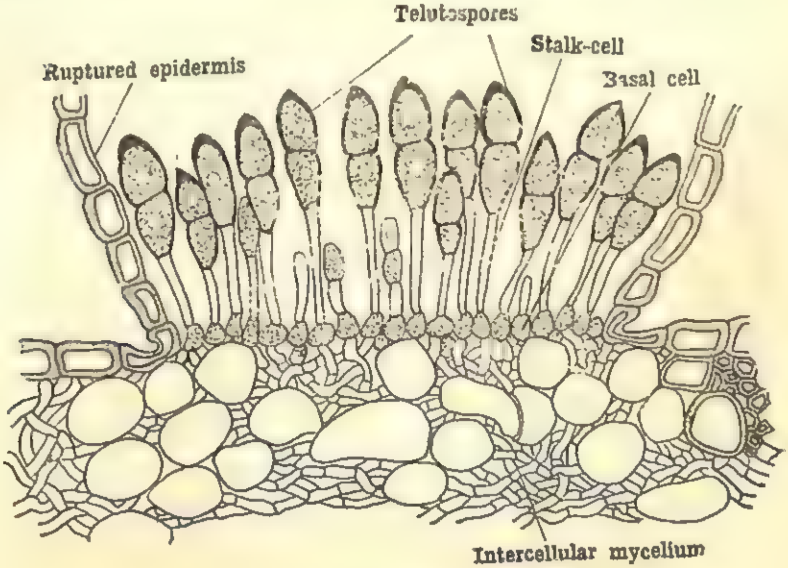

Fig. 192. *Puccinia graminis.*
Section through a teleutosorus showing teleutospores in various stages of development.

Telial (teleuto) or black rust stage. Towards the end of summer, as the wheat plants attain maturity, the mycelium, which upto this time bore uredospores, begins to produce another type of spores, called **teleutospores (teliospores, or winter spores, or black rust spores)** within the **teleutosori (telia).** At first the teleutospores are produced in a sorus containing uredospores, but later one new teleutosori containing teleutospores only develop on the host plant.) The development of a teleutospore is similar to that of a uredospore excepting that the upper sister cell of the stalk cell, instead of directly developing into a teleutospore, divides into binucleate cells, which mature into a two-celled, thick-walled teleutospore. (The teleutospores are dark-brown but in mass black in colour. Each spore, when young, is binucleate and with

a single germ pore, but as it attains maturity the two nuclei fuse to form a diploid nucleus. The spores appear on wheat stalks as narrow black streaks or sori, bursting through the epidermis of the host. The teleutospores are resting spores and do not germinate until the following spring. They tide the fungus over the winter, remaining either on the ground or attached to the old sorus on the wheat stalk. By this time the wheat crop matures fully, and further growth of the fungus is stopped.

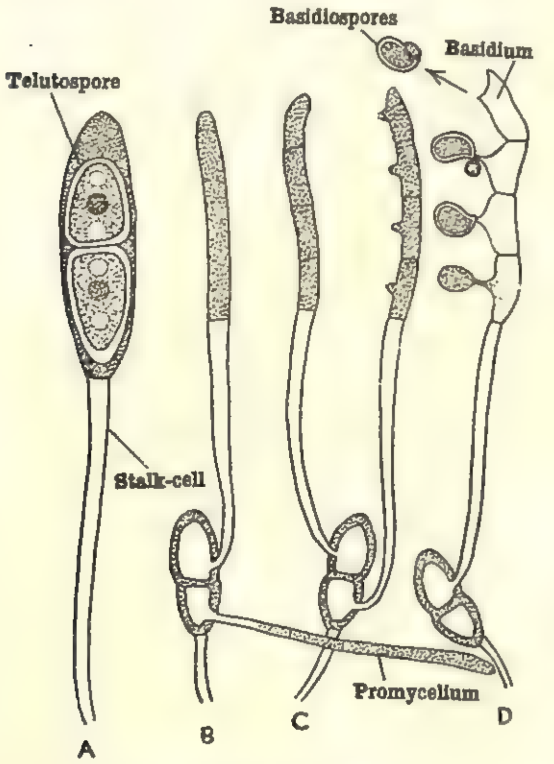

Fig. 193. *Puccinia graminis.*
A, A mature teleutospore; B—D, Stages in the germination of a teleutospore showing the successive stages of development of the basidium and the basidiospores.

Basidial stage. Under suitable conditions of temperature and moisture, a teleutospore germinates and from each of its cells a tubular outgrowth is formed. This tubular outgrowth elongates at its apex and becomes curved at its free end. The fusion nucleus migrates into this curved terminal portion, divides reductionally into four daughter nuclei, after which transverse walls are laid down forming four uninucleate cells, more or less equal in size. This is the **basidium** (**promycelium**). Each cell develops a small lateral projection, the **sterigma,** through which pass the nucleus and most of the cytoplasm. The swollen apex of the sterigma containing the nucleus becomes separated as a **basidiospore** (**sporidium**). A spore forms a small projection, at one side of it, called the **hilum,** where it joins a sterigma. At maturity, all the four spores are attached to the sterigmata somewhat obliquely and are soon

shot away in succession to the air from the sterigmata with considerable force. Just before spore discharge a small drop of water is excreted at the spore-hilum. This water drop gradually increases in volume and the spore along with the drop is violently shot away from its sterigma. *P. graminis* is heterothallic. The basidiospores, thus formed, are, therefore, of different sexes (+ and −), two are of one sex and the other two of the opposite sex. The basidiospores are incapable of infecting wheat plant, but can germinate only when they come in contact with the alternate host, the barberry.

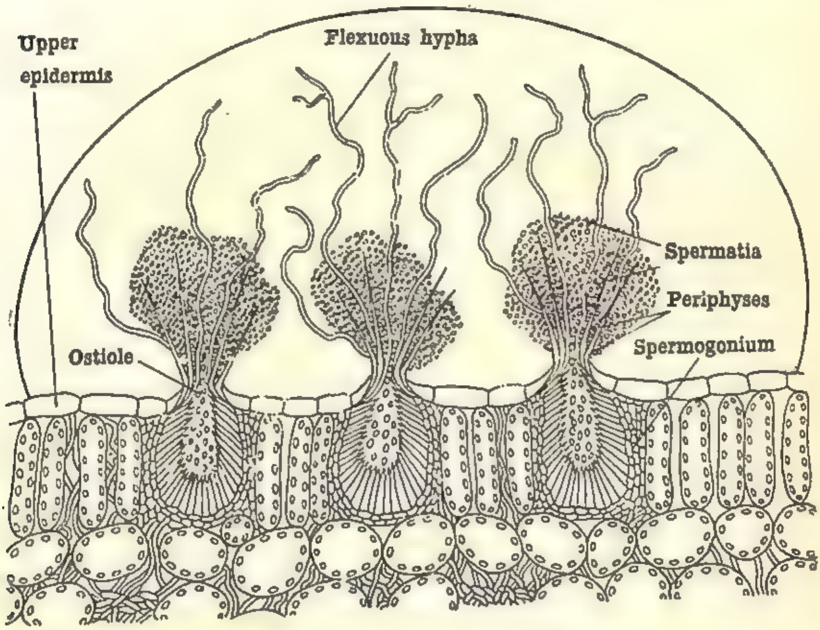

Fig. 194. *Puccinia graminis.*
Semi-diagrammatic representation of a part of a section through the upper surface of a leaf of barberry showing spermogonia covered by a big drop of nectar in which spermatia are being exuded. (*Redrawn after Buller*).

Pycnial or spermogonial stage. The basidiospores are carried away in all directions by the wind, and when they reach a barberry plant they begin to germinate. A basidiospore (+ or −), on falling on a leaf, twig or fruit of barberry, puts forth a germ tube, which penetrates directly through the epidermal cells and branches through the intercellular spaes of the host tissue forming a branched haplophasic (monokaryon) mycelium consisting of uninucleate cells. The infected areas soon become swollen and yellowish in colour.

Within 4-5 days, after infection, there appear between the upper epidermis and the palisade tissue, isolated hyphal mats, which at maturity become flask-shaped and each develops a pore-like opening, the **ostiole.** These ostioles appear as minute dark spots on the upper surface of discoloured areas on the leaves of barberry. These are known as **pycnia** (**spermogonia**). Inwardly projecting hyphae, lining the cavity of each spermogonium, cut off from their tips, a succession of small uninucleate spore-like cells, called **pycniospores** (**spermatia**), which gradually accumulate inside the spermogonial cavity. The pycniospores have gelatinous wall and these are extruded in a drop of nectar exuded through the ostiole. Besides the pycniospores, each pycnium sends out through the ostiole numerous straight, pointed, red hairs, the **periphyses,** and a small number of simple or branched **flexuous hyphae** projecting beyond the cloud of spores into the nectar. The haplophasic mycelium, the pycnia and the pycniospores are all haploid structures and may be either of the + or of the − sexual strain, depending on the nature of the basidiospore from which they develop. Individually, each pycniospore cannot re-infect the barberry plant, and was previously thought to be a spore that has become functionless. But it has been proved that they are essential structures, which are responsible for the initiation of the diplophase. This initiation of diplophase is rendered possible by the transference of pycniospores from a pycnium of one sex to another of the opposite sex usually with the help of insects. The fragrance and sugary contents of the nectar are attractive to the insects and induce them to crawl from one pycnium to another, thereby mixing the pycnial exudates of the two opposite sexes. A pycniospore of one sex usually fuses with the tip of a flexuous hypha of the opposite sex, and its protoplasmic contents finally enter into the latter; this is the initiation of the diplophase. The spermatization of the flexuous hypha may also take place by compatible pycniospores, which come in contact with these hyphae while floating freely in a big nectar drop, produced by the coalescence of a number of smaller drops exuded through the ostioles of several pycnia. How the entire haplophasic mycelium becomes diplophasic is not known with certainty.

Aecial (**aecidial**) **or cluster-cup stage.** While the pycnia are being formed towards the upper infected regions of the barberry leaf, masses of hyphae accumulate at various points just within the lower epidermis of the infected areas. These are the

rudiments of aecia (**proto-aecidia** of Buller), and are haploid structures. Presumably, after diplodization, the nuclei migrate through the hypha to an aecial initial, and as a result it is stimulated to further development. Some cells of the aecial initial become binucleate, and a layer of binucleate basal cells is formed in a manner similar to that produced in a sorus. Each basal cell, by nuclear and cell divisions, produces a chain of alternately large and small binucleate cells. The large cells mature into **aeciospores,** and the smaller ones disintegrate. These chains of spores are surrounded

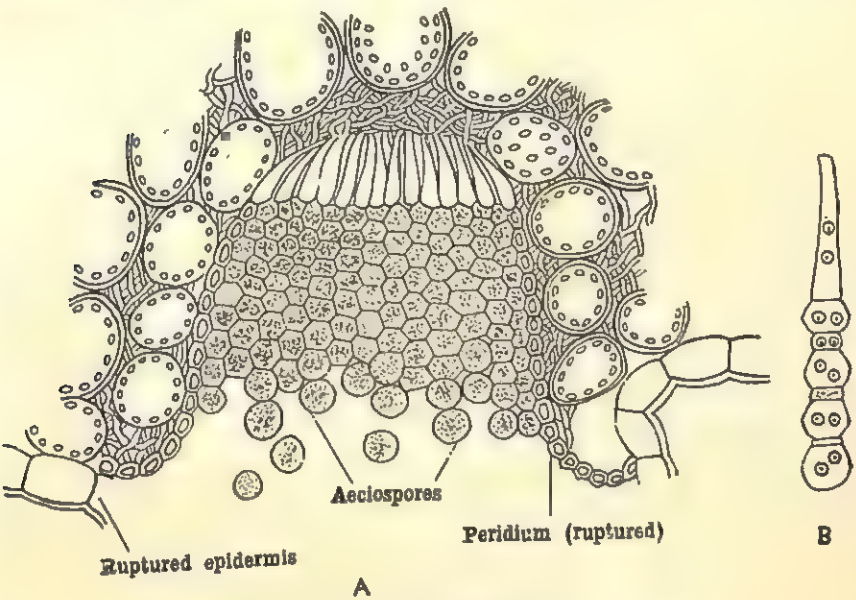

Fig. 195. *Puccinia graminis.*
A, A section through an aecium showing aeciospores in various stages of development; B, Formation of aeciospores.

by a continuous protective layer of fungal tissue, known as the **peridium,** in which the radial and outer tangential walls are greatly thickened. The entire structure is known as the **aecium** (**aecidium or cluster-cup**). At maturity, the peridium ruptures, the entire aecium becomes distinctly cup-shaped and the binucleate aeciospores are liberated. The aeciospores are always unicellular, orange or yellow in colour and with minutely warty hyaline walls.

In late spring when these aeciospores are liberated, they are disseminated by wind. They cannot re-infect the barberry, but

if a spore reaches a wheat plant, it germinates, puts forth a germ tube, which penetrates a stoma, and ultimately ramifies through the intercellular spaces of the host and again forms a diplophasic mycelium, which within 10-12 days begins to form the first crop of uredospores. Thus, in typical cases, the first infection of the wheat plant is brought about by the aeciospores.

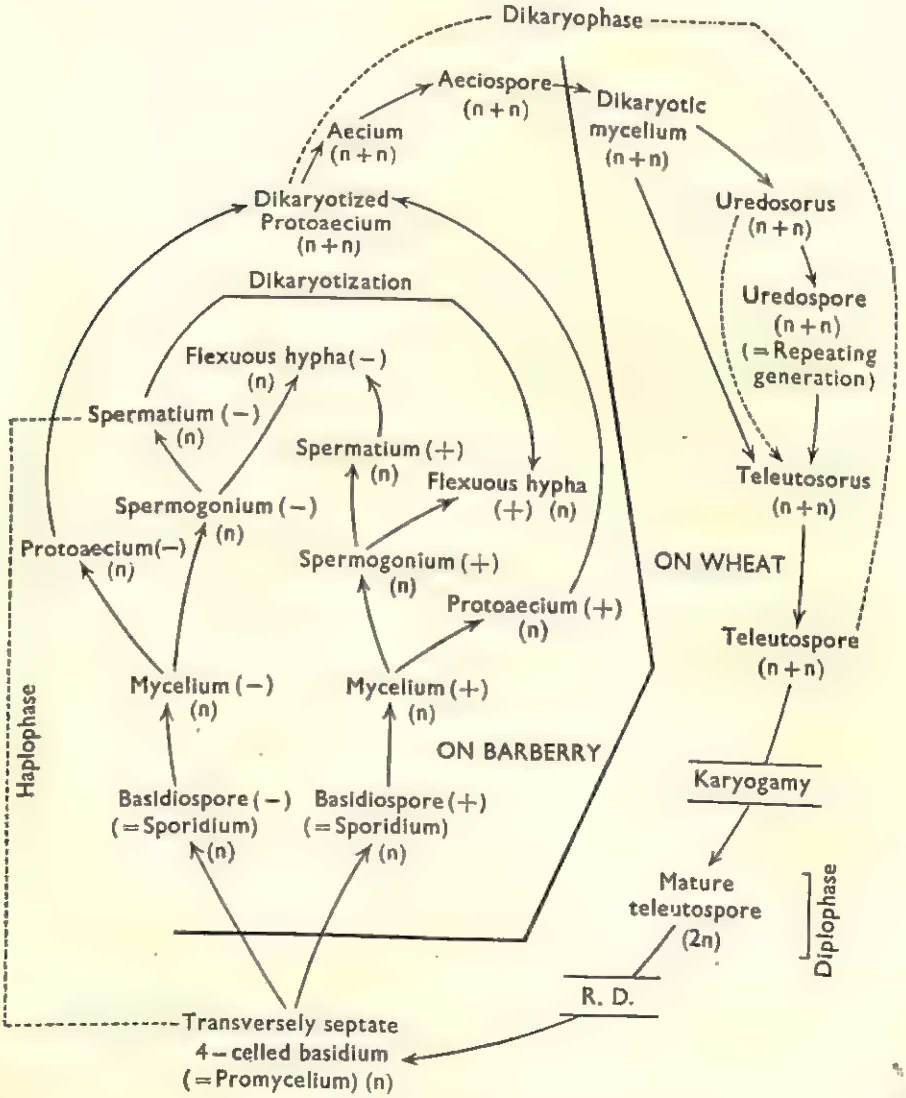

Fig. 196. Life history cycle of *Puccinia*.

The annual recurrence of *P. graminis* in the plains of India is still a highly intricating problem. Once it was thought that the eradication of barberry would be absolutely effective in controlling the disease. In fact, countries like U.S.A., Canada and some others in Europe have been able to do so. But, in our country, the majority of the wheat crop is cultivated in the plains, and not even a single barberry plant is found to be growing in the neighbourhood of these wheat-growing areas. Still the black rust of wheat every year causes great damages to the crop.

Unlike the western countries situated in the temperate zone, the first appearance of this rust is noted on the stems and leaves of wheat in late February in our country; these are the uredosori. As the climate continues to become drier and hotter, teleutosori are formed. So, in India teleutospores are really the summer spores. But the teleutrospores are not expected to survive the very high temperature (about 47°C in some cases) lasting for a few days at a stretch. Furthermore, as has already been pointed out, barberries are entirely absent in the plains; consequently, the question of aeciospore-formation can be completely ruled out. So, the focus of infection in the plains must lie somewhere else, and in fact, the hills of India can be considered as such foci. In the hills the uredospores usually oversummer on some self-grown wheat and some graminaceous weeds and cause an infection of the early sown crop in winter. The overwintering of the rust necessarily takes place on wheat at comparative lower altitudes where the winter is not so severe. From these infected sources the disease gradually spreads downwards into the plains through the agency of wind.

Besides *P. graminis*, the black rust, there are two other rusts found commonly attacking the wheat plants,—*P. glumerum*, the yellow rust, and *P. triticina*, the brown rust. A brief account of some of the macroscopic features of these three rusts is given in the following table by means of which they can be identified in the field :

P. graminis (Black or stem rust)	*P. glumerum* (Yellow or striped rust)	*P. triticina* (Brown or orange rust)
1. Attacks chiefly the stems; ears, leaves and leafsheaths are also infected but to a lesser degree.	1. Attacks mainly the leaves, also the ears, leaves and leafsheaths to some extent.	1. Attacks practically the leaves only; in rare cases infections may be found on the leafsheaths and still more rarely on stems.

P. graminis (Black or stem rust)	*P. glumerum* (Yellow or striped rust)	*P. triticina* (Brown or orange rust)
2. Uredosori large and elongated, brown in colour, coalescent and maturing early and causing conspicuous breakage or rupture of the epidermis of the host.	2. Uredosori somewhat smaller in size and oval in shape, lemon yellow in colour and not coalescing but arranged in rows or stripes, maturing late and the epidermis of the host is slightly displaced by the rupture of the sori.	2. Uredosori usually smaller than those of *P. graminis* but longer than those of *P. glumerum*, orange-coloured when young but turning brown on maturity, scattered irregularly and not coalescing, maturing rather early, and the broken epidermis of the host remains as a fringe around a ruptured uredosorus.
3. Teleutosori almost like uredosori but black or dark-coloured, cause heavy rupture of the epidermis of the host; found practically speaking on all aerial green parts.	3. Teleutosori like uredosori but dull black in colour and often coalescing, not causing any rupture of the epidermis of the host; found mainly on the lower surfaces of leaves, but occasionally on the aerial green parts.	3. Teleutosori generally absent otherwise like uredosori but somewhat flat and dark in colour, not causing any rupture of the epidermis of the host; found almost exclusively on the lower surfaces of leaves.

Control measure

From the discussions above, it is evident that eradication of barberry plant will not be effective in controlling the black rust in India. This was the well-considered opinion of late Principal Mehta, the pioneer worker and authority on cereal rusts in India. Practically speaking, the only effective control measure for combating the disease lies in cultivation of resistant varieties of wheat, and for this purpose crossings of our wheats with Kenya wheats have yielded some satisfactory results.

ORDER **HYMENOMYCETALES**

Chiefly saprophytic and often with prominent subaerial fructifications; hymenium variously disposed but always exposed (at least at maturity); basidium never septate.

POLYPORUS

(Fam. Polyporaceae)

Of the various species of the genus *Polyporus* so far described from Bengal, *Polyporus ostreiformis* is a common saprophyte, which grows singly or in groups during the rainy season on logs and stumps of various trees, ultimately causing their decay. It is a

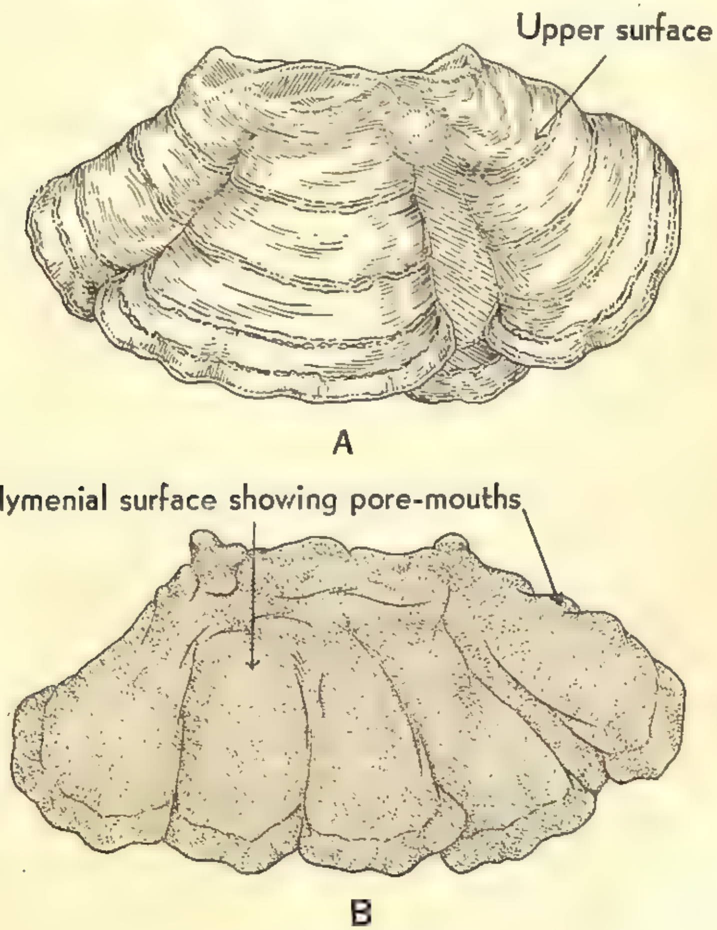

Fig. 197. *Polyporus*.
A, Dorsal view of a sporophore; B, Ventral view of the same.

white rot fungus, because it can attack both cellulose and lignin constituents of the cell walls. It has also been reported as a parasite causing a disease of areca palm in Malayasia.

Vegetative body

The mycelium, which lives within the woody tissues, is both inter- and intra-cellular and consists of much-branched, septate and white hyphae, by means of which the plant not only vegetates but also draws nourishment from the substratum. There are two phases in the development of the mycelium, *viz.*, (1) **monokaryon phase,** consisting of uninucleate hyphal cells, and (2) **dikaryon phase,** in which the hyphal cells are constantly binucleate. Since it is a basidiomycetous fungus, the mycelium derived from the germination of a basidiospore is always in the monokaryon or primary stage. According to Prof. S. R. Bose, the fungus is heterothallic and sexually 'bipolar'. As such, the basidiospores produced by a basidium are of two sexes. When these basidiospores of two opposite sexes germinate, they give rise to two types of monokaryon mycelia of respective sexes. Between these mycelia anastomosis is common. When anastomosis takes place between mycelia of opposite sexes, nuclei of one pass into the other, as a result the cells of the latter are diplodized. From these diplodized cells, ultimately a typical dikaryon or secondary mycelium develops and this is characterized by the presence of dikaryotic hyphal cells and clamp-connexions. Furthermore, the branches of the main strand or hyphae in primary mycelium develop almost at right angles to the main hypha, whereas in the secondary mycelia they grow at acute angles. Besides, in the primary mycelium the clamp-connexions are entirely absent. After the mycelium accumulates a considerable store of food, **sporophores (or fructifications or fruit bodies)** of the fungus are produced from the secondary mycelium.

The sporophore

Typically, a mature sporophore is a sessile and bracket-shaped structure. Its upper surface is smooth, whitish or greyish in colour and occasionally with faint zonations towards the margin or edge of the fructification. When moist, it is leathery in texture but becomes hard and somewhat incurved on drying. When cut across it consists of two distinct regions: (1) **context,** the thick, homogeneous, white and fleshy portion just below the upper surface, and (2) **pore-tubes,** consisting of comparatively long tubes which form a single layer below the context. These pore-tubes occur at the lower or hymenial surface. The pore-mouths on the

hymenial surface are regular and more or less circular in cross-section. The hymenial surface is also smooth, whitish, or greyish in colour, and with a shining lusture. Sections through the pore-tubes reveal the presence of **basidia** forming a **hymenium,** which lines the inner surface of each pore-tube. The basidia are club-shaped and each bears four **sterigmata** with four **basidiospores.** The basidiospores are hyaline, more or less oblong in shape, and flattened at one side. At maturity, the basidiospores are discharged by 'water-drop mechanism'. The basidia always develop from

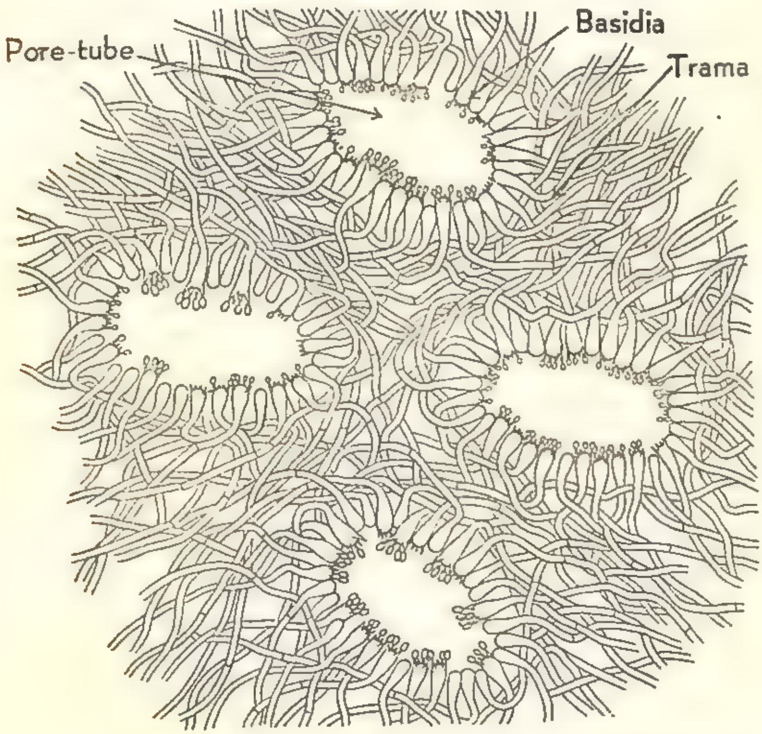

Fig. 198. *Polyporus.*
T. S. of a mature fruit body showing basidia, basidiospores, etc.

the terminal cell of the dikaryotic hyphae that project into the cavity of each pore-tube.

After the basidiospores are shed, they germinate under favourable conditions by putting forth germ tubes, from which primary mycelia of different sexes are derived.

AGARICUS (= *PSALLIOTA*)

(Fam. AGARICACEAE)

Agaricus campestris (= *Psalliota campestris*), the common edible gilled mushroom, is the species that is cultivated for the market. It is a saprophyte which grows, singly or in groups, during the rainy season in pastures, grassy places, richly manured unploughed fields, but never in thick woods. In open field, sometimes the fruit bodies of the fungus come up forming small or large rings, the so-called **fairy rings.**

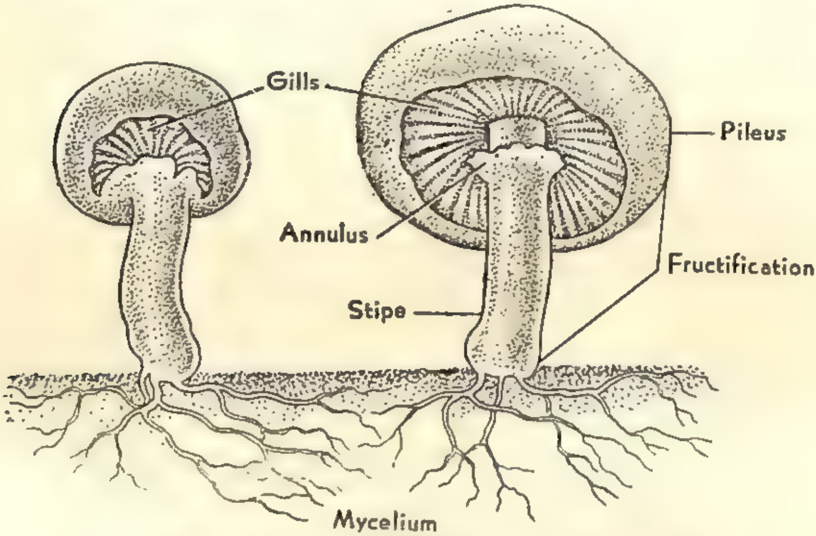

Fig. 199. Mycelium and fruit bodies of *Agaricus campestris*.

These rings are perennial and increase very slightly in diameter every year. Lying enclosed within the fairy ring there are usually a number of concentric rings of grasses, of which the outermost one, that is the one lying just in contact with the fairy ring, is quite healthy and luxuriant, as also is the innermost one. On the contrary, the intermediate ring of grass is extremely depressed in growth or may even be completely dead. The luxuriance in growth in the outermost ring is most probably due to the action of vigorously growing and centrifugally radiating mycelia on the various proteins and other organic materials present in the soil, thereby liberating a good deal of ammonia. The nitrifying soil bacteria convert this into nitrate which is ultimately utilized by the grasses

as their food. On the other hand, the depression of growth in the intermediate grass ring can be explained by the fact that the water relations of the soil are unbalanced to a great extent by the fungal mycelia ramifying within the soil, consequently causing a drought during the dry season, and hence, causing damage to the zone.

The body of the fungus consists of two parts, namely: the vegetative portion or the **mycelium,** and the **sporophore** (or **fructification** or **fruiting body**), concerned with the reproduction of the plant.

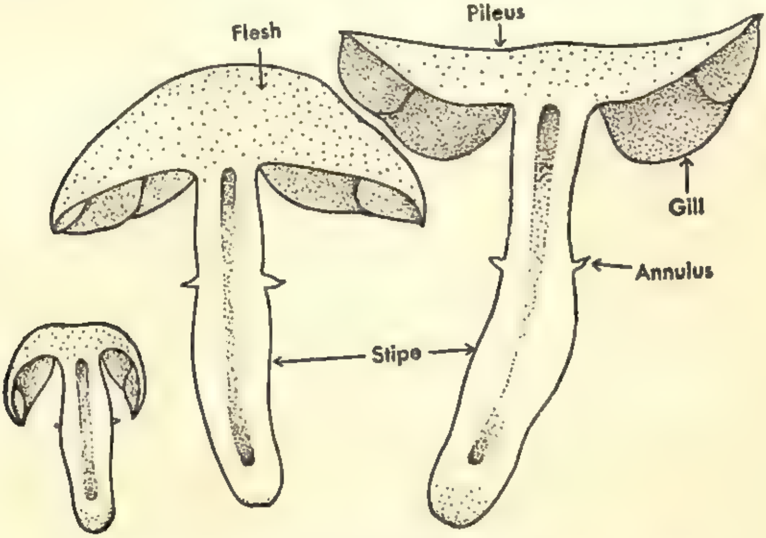

Fig. 200. *Agaricus.*
Median longitudinal section through the fruit bodies showing different parts.

Vegetative body

The mycelium, which is perennial and subterranean, consists of extensively branched strands of septate, white hyphae, by means of which the plant not only vegetates but also draws nourishment from the substratum. The hyphal cells contain granulated, vacuolated and multinucleated (in most cases with twelve or more nuclei) protoplasm containing droplets of oil as reserve food. Hyphae of a centrifugally developing mycelium may be free from one another or may unite to form small rope-like strands, called **rhizomorphs.** When reproduction becomes necessary and after the mycelium has accumulated considerable stores of food, sporophores or the repro-

ductive bodies of plants are produced on the rhizomorphic portion of the mycelium.

The sporophore

Typically, a mature sporophore consists of two parts: The **stipe** (about 5 to 8 cm. long, and 0·8 to 1·8 cm. in diameter) is the stalk-like portion which is composed of united aerial hyphae. It is at first solid and bulbous, but later on cylindrical and tapering below, and whitish in colour. In the stalk a broad, thin, white, fragile ring or **annulus** is also present. The stipe bears at its top an umbrella-like structure, known as the **pileus** (4 to 9·5 cm.

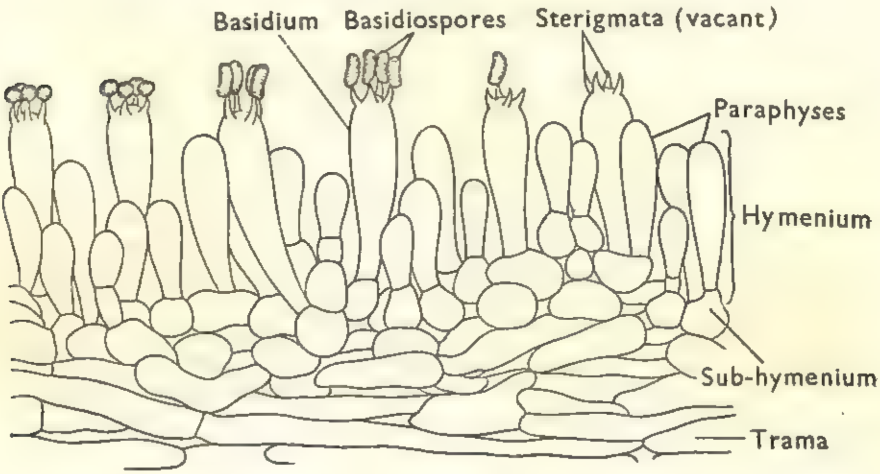

Fig. 201. *Agaricus.*
An enlarged portion of a lamella in section showing the different regions.

in diameter), which is at first more or less convex, thin, flat, dry, smooth, soft, usually satiny white in colour, sometimes with minute brownish scales (triangular) and with a thin, wavy, white and delicate margin. The upper thick and white part of the pileus is known as the **flesh,** on the underside of which some delicate white to pink or flesh-coloured, thin, plate-like structures are seen to hang. These are called the **gills** or **lamellae** (0·6 to 1·6 cm. broad in the middle and with 300 to 600 gills per pileus). The gills, which are free from the stipe ultimately become purple-brown to chocolate-brown to almost black with age, and they radiate outwards from the stalk towards the margins of the pileus.

A cross-section of the gill reveals, under the microscope, the following regions: (*a*) a central portion, the **trama,** consists of elongated multinucleate hyphal cells, which terminate both ways, right and left, to (*b*) **subhymenium** layers consisting of more or less circular hyphal cells (innermost cells multinucleate, outer ones binucleate) which end in (*c*) the **hymenium,** mainly composed of closely-packed, club-shaped cells known as **basidia.** Thus, each surface of the gill is covered with a layer of hymenium, the cells of which grow at right angles to its surface.

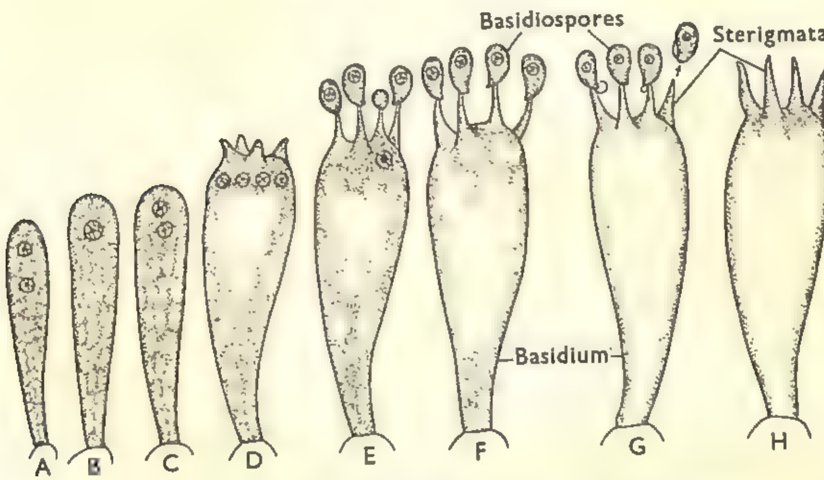

Fig. 202. *Agaricus*.
A—H, Diagrams showing successive stages in the development of the basidium and basidiospores, etc.

The basidia are really the spore-mother cells. Each basidium is binucleate at its first formation. These nuclei fuse to form a diploid nucleus which soon undergoes reduction division. After reduction division, four haploid daughter nuclei are formed, which furnish the nuclei of the basidiospores. Each basidium produces four **sterigmata,** through each of which a nucleus passes out to form a purple-brown or violet-brown, slightly kidney-shaped, thick-walled, uninucleate **basidiospore** (usually with a highly refractive oil globule) at the tip, so that four basidiospores are produced on each basidium. Each spore, when separated, is provided with a small, eccentrically placed spine-like projection at the basal

end, the former point of attachment of the sterigma. At maturity, just before the spore discharge, a drop of water appears at the **spore hilum.** When the water drop attains full size, the spore is shot off with considerable violence.* The spores fall to the ground and under suitable conditions begin to germinate. Each spore, at the time of germination, becomes multinucleate and contains oil globules. On germination, it puts forth one, two, or even three, spherical or irregularly shaped germ tubes from any point, which ramifying profusely produce a new mycelium.

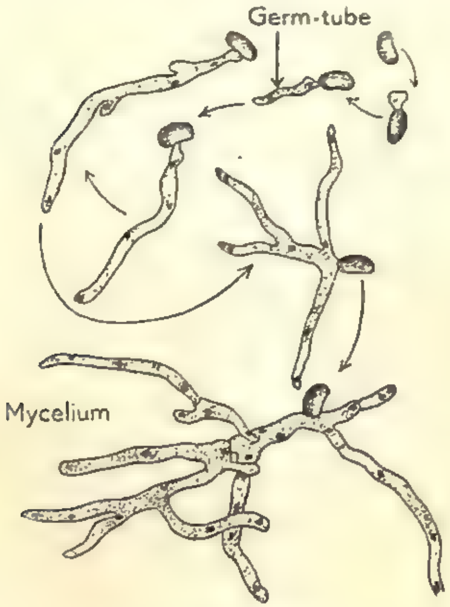

Fig. 203. *Agaricus.* Successive stages in the development of a mycelium from a germinating basidiospore.

There are irregular ways of basidial development in a hymenium of *Agaricus*, which consists of five types of elements, according to Buller, *viz.*, (1) basidia of past generation that have already discharged their spores, (2) basidia of present generation with mature spores ready for discharge, (3) basidia of succeeding generation with developing sterigmata and immature spores, (4) basidia of future generation (erroneously called **paraphyses**) which have not yet formed sterigmata and spores, and (5) paraphyses.

The paraphyses are destined to be sterile from the first, become vacuolated early, and swell up considerably during the gradual development and final collapse of the basidia. The paraphyses are much smaller in size than the basidia and are visible as living cells when all the basidia in the hymenium are collapsed and have discharged their spores.

* "A single spore (1) takes 30 to 40 minutes to grow from a tiny rudiment to a full size, (2) remains colourless for the next 2 hours, (3) gradually becomes pigmented during the next 2 hours, (4) remains in the fully pigmented condition on the end of its sterigma for further 3 hours and about 10 minutes, and (5) is then discharged."—Buller, 1942.

ORDER GASTEROMYCETALES

As in the Order Hymenomycetales but with fructifications either subterranean or subaerial; hymenium remains closed within the peridium until the spores have attained maturity; basidium always aseptate.

PHALLUS

(Fam. PHALLACEAE)

Phallus impudicus, one of the well-known 'stink horn' fungi, is commonly found as saprophyte that grows in humus soil as well as on decaying wood and sawdust piles around the timber yards during the rainy season.

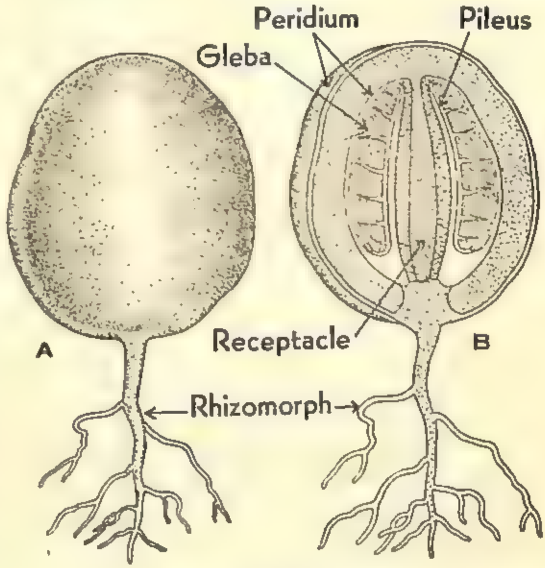

Fig. 204. *Phallus.*
A, A developing fruit body; B, Median longitudinal section of the same.

Vegetative body

The mycelium is subterranean and consists of irregularly-branched, white and septate hyphae which are often organized into smooth, string-like **rhizomorph.** The rhizomorph has a central prosenchymatous core and a pseudo-parenchymatous cortical sheath. The hyphal cells are mostly dikaryotic and shows typical clamp-connexions, but nothing is known about the existence of the monokaryon phase of the mycelium or about the manner in which the dikaryon mycelium is formed. Occasionally, a rhizomorph develops into an irregularly shaped **sclerotium.**

The sporophore

When reproduction becomes necessary the mycelium bears,

from its rhizomorphic portion, one to several **fructifications** or **sporophores,** the reproductive structures of the fungus. The fundament of a sporophore develops at the apex of a rhizomorph and during its development it remains hidden under the humus. The young sporophore soon increases in diameter and attains the size and shape of a hen's egg. At this stage, it consists of a wall, called the **peridium,** which is differentiated into an outer (**exoperidium**) and an inner (**endoperidium**) layers. The peridium encloses an internal fertile tissue, known as the **gleba.** Between exo- and endo- peridia there develops, at an early stage, a gelatinous layer, which is formed due to the disintegration of some of the hyphae. The exoperidium is continuous at the base of the fruit body with a sterile column, or **receptacle,** running up the middle of the gleba. The gleba originates from the peripheral region of the internal tissue just within the endoperidium. It is differentiated into a number of closed chambers, each being lined internally by the hymenium. Very little is known about the development of **basidia,** but it is known that the young basidia are binucleate and formed early. Mature basidia are club-shaped, and each bears eight **basidiospores** on sterigmata at the apex. The tissue of the upper portion of the receptacle, lying just within the gleba, develops into a sterile **pileus,** while its basal portion forms a hollow **stipe**.

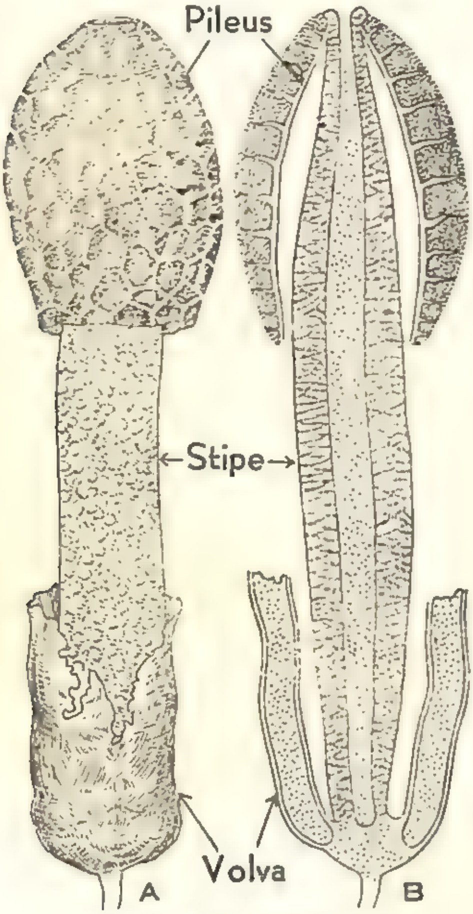

Fig. 205. *Phallus*. A, A mature fruit body; B, The same in median longitudinal section.

subsequently developing into a mature sporophore of the 'stink horn'.

When the spores become ripe a mucilagenous, viscous matrix replaces the gleba, and this is formed by the disintegration of the basidia and the sterile glebal tissues. In this sticky matrix the spores remain embedded.

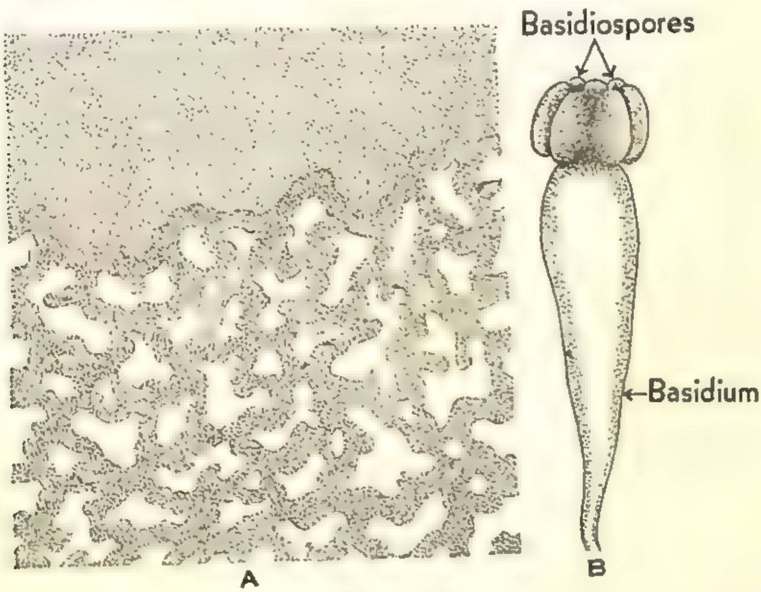

Fig. 206. *Phallus.*
A, T. S. of a part of the sporophore; B, A basidium with basidiospores.

The unopened sporophores, commonly known as the 'eggs', may remain in this condition for a considerable time, but at any time with the approach of favourable conditions the elongation of the stipe begins, the peridium is ruptured, and the pileus with the sticky and gelatinous spore-mass is carried up into the air. Full development of the fructification takes place about half an hour or more, after the rupture of the peridium. When fully formed, the sporophore consists of an apical pileus covered by the viscous spore-mass and a hollow, chambered stipe filled internally with mucilage. The ruptured peridium forms a cup-like structure, known as the **volva,** at the base of the stipe. The sporophore emits foetid smell, characteristic of the fungus, and also a sweetish taste of the disintegrated gleba attracts various types of

flies, which act as the major agency for spore-dispersal. Spores may also be discharged due to rains which wash down the basidiospores from the pileus. The spores, under favourable conditions, germinate giving rise to mycelia, but nothing so far is known concerning spore-germination and the origin and nature of the mycelium.

LYCOPERDON

(Fam. LYCOPERDACEAE)

The members of the genus *Lycoperdon* are commonly known as '*puff balls*'. They are usually found to grow singly or in clusters on the ground in the woods, sometimes on grassy lands or in open fields. Almost all the species are edible at their young stage. The fruit bodies are more or less pear-shaped with a thick, sterile stalk and they are variable in size.

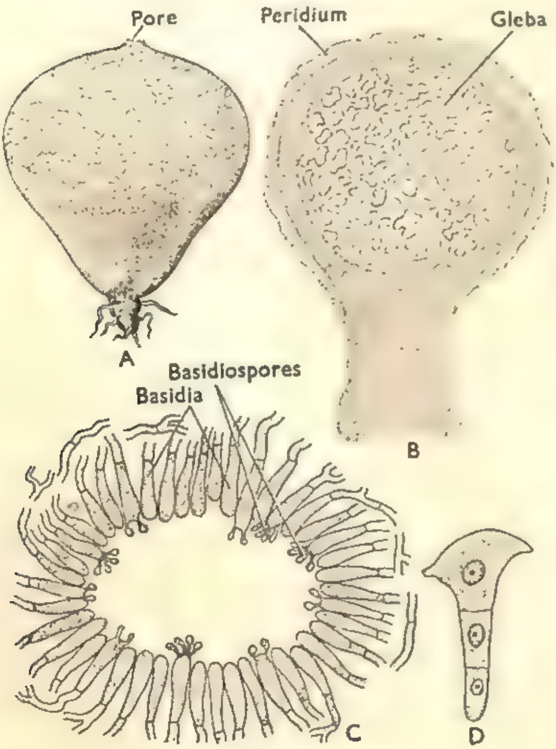

Fig. 207. *Lycoperdon.*
A, A mature fruit body; B, V. S. through a young fruit body; C, Section through the gleba showing the hymenial layer and the glebal cavity; D, A germinating basidiospore.

Vegetative body

The primary mycelium is much-branched consisting of short uninucleate cells. The secondary mycelium developed from the primary mycelium may form several **rhizomorphs.** Each rhizomorph is a complex structure, usually composed of an outer cortical

layer of loose hyphae, a subcortical layer of compact hyphae, and a central core of parallel hyphae.

The Sporophore

At the time of reproduction, small hyphal knots develop at the tips of the rhizomorphs. These are the primordia of the **fruit bodies** or **basidiocarps.** In early stage, the young primordium is a homegeneous structure, usually about 5 mm. in diameter but gradually, with age, they are differentiated into a sterile outer layer, the **peridium,** and an inner fertile region, the **gleba.** The peridium is also differentiated into two portions, the outer pseudo-parenchymatous layer, the **exoperidium,** and the inner palisade-like layer, the **endoperidium.** As the basidiocarp increases in size, numerous, small, irregular cavities are distinguished inside the gleba, and these cavities are usually lined with loose interwoven hyphae. From these hyphae, eventually, the young **basidia** are developed. This type of gleba is known as the **lacunose gleba.** Each young basidium at first contains two nuclei, but after karyogamy one fusion nucleus is formed. This fusion nucleus divides reductionally and gives rise to four nuclei. Meanwhile, four sterigmata are usually developed on each basidium and each of the sterigmata finally bears one **basidiospore.** The 4 nuclei of the basidium then migrate to the four basidiospores through sterigmata. When the spores attain maturity, they are collected inside the cavities. These spores with other glebal contents together form the **capillitium.** At maturity of the basidiocarp, the outer peridium withers away and subsequently, the inner peridium develops a pore at the top and as soon as the basidiocarp is pressed by any external force, the spore masses are discharged through the pores. In this case, the pressure may be exerted by wind or by large rain drops, sometimes by animals as well.

CYATHUS

(Fam. NIDULARIACEAE)

Cyathus is a very common saprophytic fungus found both in the eastern as well as the western hemispheres, growing on dead or decayed logs of wood or on humus soil. It is popularly known as the "birds' nest fungus."

The sporophore

The vegetative body of the fungus is an extensively branched mycelium which finally gives rise to a subaerial infundibuliform fruit body, the **sporophore** or **spore fruit.** Each sporophore has a thin or thick peridium and a large number of hymenial cavities lie within the gleba. The peridium is differentiable into three layers : an **exoperidium,** an **endoperidium** and a **pseudoparenchymatous zone** lying in between the two. Each hymenial

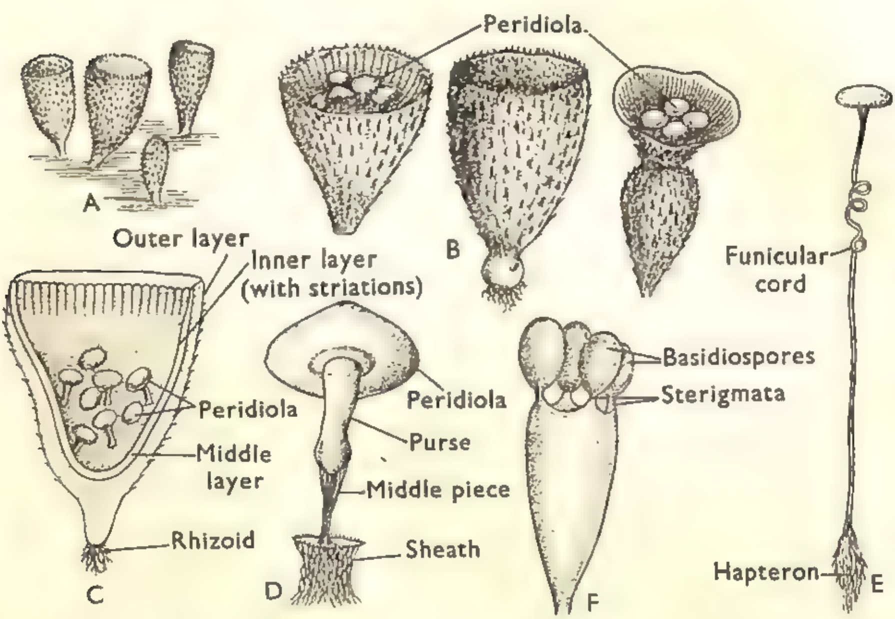

Fig 208. *Cyathus*.
A, A group of fructifications ; B, Three fructifications (in magnified view), two of them showing peridiola; C, V. S. through a fruit body ; D, A mature peridiolum with its associated parts; E, A disseminated peridiolum ; F, Basidium with basidiospores.

cavity is lined internally by a basidial layer containing basidia and basidiospores and externally by a several-layered wall formed by the trama. Consequently, a number of thick-walled structures known as **peridiola** are formed. A peridiolum is connected with the interior of the funnel, near about its base, with the help of a delicate thread-like mycelial strand known as the **funiculus,** which remains much coiled in a dry weather. But, when moistened, it uncoils and attains a length of even 10-15 cm. At such a stage the

base of the funiculus, the **hapteron,** becomes very much sticky and adherent. The funiculus in fact, consists of three parts : **sheath, middle piece** and **purse.**

The peridiola are ruptured as a result of rupturing of the peridium and are disseminated on maturity in a very interesting fashion. During the rainy season when rain drops strike the funnel, the peridiola are ejected out, the purse gets torn open, with the funicular cord uncoiled and hapteron extended. These haptera being extremely sticky in nature attach themselves with any solid object with which they may come in contact. The basidiospores begin to germinate within the peridiolum and a large number of germ tubes are produced. Martin (1927) suggests that the basidia collapse before the basidiospores have attained maturity and under such conditions a tuft of hyphae, which surround each spore, supplies it with nourishment. Each basidiospore on germination gives rise to a new mycelium.

CLASS IV. DEUTEROMYCETES (FUNGI IMPERFECTI)

The Deuteromycetes include those fungi, in which the 'perfect stage' is unknown. The term perfect stage means the stage in the life cycle in which the ultimate sex structures, like oospores, zygospores, asci, basidia, and teleutospores, etc., are formed. The vegetative body of these fungi are always septate mycelia, hyaline or coloured, much-branched and having hyphal cells usually with variable number of nuclei. Most of them reproduce by means of accessory spores, the **conidia,** which are characteristically different in form, colour, and septation from species to species. In many cases **chlamydospores** are produced in artificial cultures. Sometimes the vegetative bodies develop **sclerotia,** from which, under suitable conditions new mycelia are produced. They live either saprophytically or parasitically, and many of them are responsible for causing important diseases of the various crop plants.

Deuteromycetes are usually divided into *four* Orders, which are characterized as follows :

Conidia borne on superficial conidiophores, simple or branched, single or united into bundles, or conidiophores developed from a stromatic structure made up of matted hyphae	**Moniliales** (e.g., *Helminthosporium*, *Curvularia*, *Alternaria*, *Fusarium*, etc.)

Conidia produced within a flask-shaped or globose structure made up of plectenchyma, opening by means of an apical pore or ostiole, and embedded in a substratum ..	**Sphaeropsidales** (e.g., *Phyllosticta, Dendrophoma,* etc.)
Conidia produced in acervuli, which are saucer-shaped stromatic structures formed within the hosts, bearing conidiophores on their surfaces, and finally exposing the spores by the rupture of the overlying tissues ..	**Melanconiales** (e.g., *Colletotrichum, Pestalotia,* etc.)
Conidia unknown	**Mycelia sterilia** (e.g., *Rhizoctonia*)

ORDER MONILIALES

Conidia borne on superficial conidiophores, simple or branched, single or united into bundles, or conidiophores developed from a stromatic structure made up of matted hyphae.

HELMINTHOSPORIUM

(Fam. Dematiaceae)

The genus *Helminthosporium* is of considerable economic importance, because several species of this genus are responsible for bringing about a colossal devastation by their pathogenic action on the cereal crops of our country. As a result of the severe infection of the fungus, the yield of the cereal grains is abnormally decreased, and at the same time the quality of the grains become very poor. Sometimes the seedlings are seriously attacked, and they ultimately succumb to the disease. Among the various species, *H. oryzae* causes the most common **leaf spot** disease of rice, and in Bengal particularly, it occurs as a parasite on both the rabi and kharif crops. It has been observed that the infection caused by the pathogen may not necessarily be a systemic one only but also a localized one as well. It may also be noted that certain external agencies, *e.g.*, continuous rainy days, cloudy weather, and irrigated field, etc., also add incentive towards the spread of this disease.

At first small brown spots are usually observed on both the surfaces of the leaves, intensity being greater specially on the lower surface. With age, the colour gradually changes from brown to dark brown with a yellowish tinge at the margin of the spots. As the number of spots increases, they finally unite to form irregular

areas, and the colour of the leaves changes to greyish-yellow. When the infection is intense, the colour of culms also turns to yellow, and eventually becomes dark brown. Lesions appear on or near the lower joints of the rachis, and the glumes are first attacked at the junction of the outer and the inner ones. Owing to severe infection of the fungus, the ears may be sterile and the grain formation may be totally stopped.

Fig. 209. *Helminthosporium.* A, Infected leaf; B, Infected ear.

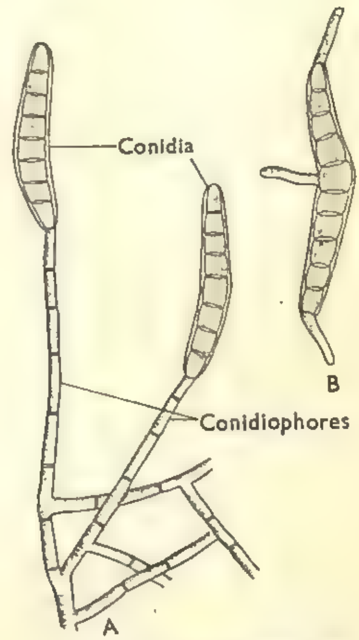

Fig. 210. *Helminthosporium.* A, Conidiophores with conidia; B, A germinating conidium.

Vegetative body

The vegetative body of the fungus is a branched mycelium, consisting of septate hyphae, which are generally found in intra- and inter-cellular regions of the host.

Reproduction

Sometimes branched or unbranched, erect, and septate **conidiophores** arise from the mycelium through the stomata, and rarely through the ruptured epidermis. The conidiophores bear terminally, and sometimes laterally, a more or less cylindrical or

obclavate, multiseptate (generally 5-10 septa) and brown **conidia.** The conidia are ultimately discharged from the conidiophores, germinate under suitable conditions and infect other plants.

Control measure

Regarding the control of the disease, no successful measures have yet been precisely known. Since the seeds are infected both externally and internally, the familiar methods of control do not provide any fruitful result, the only way out being to select the 'immune' varieties.

ALTERNARIA

(Fam. DEMATIACEAE)

Alternaria is a pathogenic fungus causing diseases in a number of crop plants. Of the different species, *A. solani* is the one, which has been investigated in detail.

A. solani causes a disease in potatoes which is known as the **early blight.** The disease occurs widely in India and abroad. In the plains of India, however, it is the most ravaging disease of potatoes caused by any fungus.

The potato plant may be infected by the pathogen almost during any stage of its development. It has been noted, however, that the plant is usually attacked vigorously only when it has tided over its period of maximum growth.

The outward symptom of the 'early blight' disease appears as a few irregularly scattered, small, isolated, and pale-brown coloured spots appearing on the leaf surface. At first there may be a few spots only, but under favourable conditions, they increase in number. In case of virulent attack spots appear on petioles and even on stems. The infected leaves gradually begin to wither from base upwards leaving only a few near about the apex. After the leaf is dead, the spots begin to increase in size with their growth, they appear to be irregularly circular with a number of concentric ridges, and often provided with a spreading out, narrow and faded peripheral zone.

Vegetative body

The vegetative body of *A. solani* is a mycelium, which is composed

of sparsely branched, septate hyphae. These hyphae are narrow, light-brown coloured, radiating and ramifying within the intercellular spaces of the invaded host tissue; they also penetrate into the cells. So, the fungus is intercellular as well as intracellular in nature. On maturity, the mycelium becomes rather irregular and closely branched.

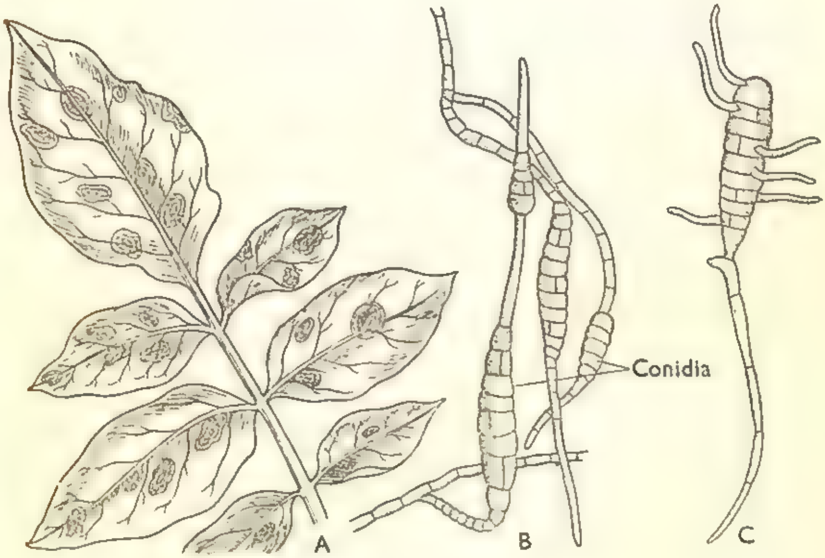

Fig. 211. *Alternaria*.
A, Leaflets of potato infected with the pathogen; B, Conidia; C, A germinating conidium.

Reproduction

Reproduction in *A. solani* takes place only with the help of **conidia.** From the spots the **conidiophores** come out through the stomata bearing conidia. The conidia are usually five-to-ten-septate, and generally obclavate in shape; occasional longitudinal septa are also frequently noted. Each of them is borne singly on the conidiophore and ends in a long, septate, tapering beak, which is sometimes branched. If the weather is moist a conidium readily germinates, and puts forth five to ten germ tubes. These germ tubes usually enter a fresh host through the stomata, but in rare cases a direct penetration has been recorded, where a germ tube pierces straight through the wall of the epidermis.

Control measures

The disease becomes very widespread when there is plenty of moisture and a corresponding high temperature unsuitable for the host plant. On the other hand, it is checked as a result of continued drought. The primary infection from the soil can be controlled by practising crop rotation. A proper spraying of Bordeaux mixture is also very much helpful in controlling the disease.

FUSARIUM

(Fam. TUBERCULARIACEAE)

Fusarium, like *Alternaria*, occurs on a number of crop plants. *F. udum* is an economically important species, since it causes the most serious type of damage to the pigeon peas (*Cajanus cajan*) by causing the **wilt disease.** The disease is particularly destructive in Bihar, Madhya Pradesh, Uttar Pradesh, and some parts of Maharastra.

The pathogen enters the host through the delicate branch roots and possibly the root hairs, but never through any subaerial part. The first visible symptoms of the disease appear when the plant is only about one and a half month's old. The leaves of the infected plant become prematurely yellow and then wither; finally, the whole plant becomes dried up, and dies very quickly. Wilting, in some cases, may be partial, when only the attacked parts become dry. The vascular tissues of the root and stem of an infected plant reveal on examination the appearance of thin or thick black streaks, depending on the stage of the disease.

Vegetative body

The vegetative body of the fungus is a hyaline mycelium, which is both intracellular as well as intercellular in nature, being restricted, as a rule, to the vascular tissues. The hyphae are branched and septate, which grow profusely within the tracheal lumens and subsequently become matted and coiled, thus clogging the lumens. The pathogen also exerts toxic influences on the adjoining living cells by secreting harmful substances.

Reproduction

The reproduction in *Fusarium* takes place by means of **conidia**

and **chlamydospores** produced within the host tissues. The chlamydospores are thick-walled, and may occur either singly or in chains, either terminally or in an intercalary fashion. They are more durable and viable than the conidia. The conidia are of two types: **macroconidia** and **microconidia.** Both these types of conidia are formed on **conidiophores.** The former are long, somewhat curved and pointed at both the ends, and are generally provided with a number of septa. On the other hand, the latter are small, curved or elliptical bodies, either unicellular or provided with one or two septa only.

These conidia and chlamydospores remain viable for a considerable length of period in the soil. When the crop is sown in such a soil, it gets readily attacked by the germinating spores.

Another important species of *Fusarium* is *F. vasinfectum* causing the 'wilt disease' of cotton. The disease can be found in different parts of India, but particularly in Madhya Pradesh and Maharastra, as it is restricted to black cotton soils. The pathogen enters into the

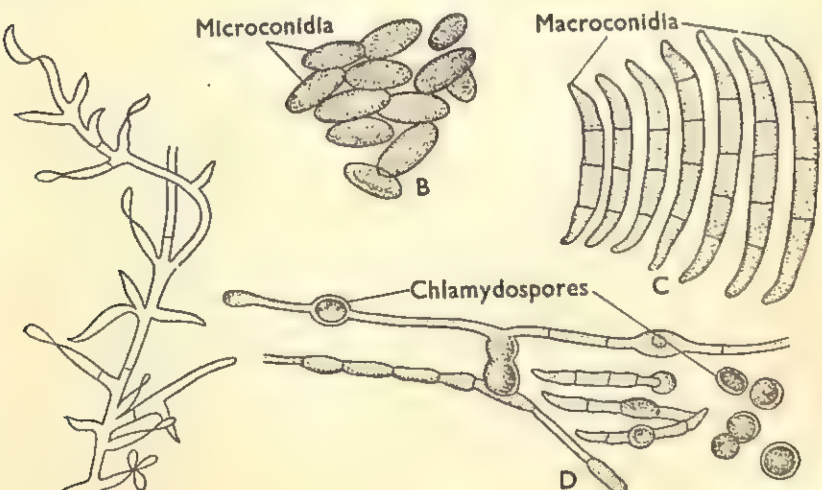

Fig. 212. *Fusarium.*
A, Formation of microconidia on conidiophores; B, Microconidia; C, Macroconidia; D, Different forms of chlamydospores.

body of the host, when it is only one to three weeks old. The symptoms and etiology of the disease are like those caused by *F. udum* in pigeon peas.

Control measures

The wilt disease cannot be controlled effectively by any direct treatment. The intensity of the disease can, however, be minimized by the rotation of crops. The best method for controlling the disease is the cultivation of suitable resistant varieties.

ORDER MELANCONIALES

Conidia produced in acervuli, which are saucer-shaped stromatic structures formed within the hosts, bearing conidiophores on their surfaces, and finally exposing the spores by the rupture of the overlying tissues.

COLLETOTRICHUM

(Fam. MELANCONIACEAE)

Colletotrichum causes diseases on several crop plants in India and abroad. Of the different species, the one that attacks the sugarcane, is very important from the economic standpoint of view. The most destructive fungal disease of the sugarcane is the **red rot** due to *C. falcatum*. Practically, it can be found in any country wherever the sugarcane is commercially cultivated. In India it occurs in almost all the States.

All the subaerial parts of the sugarcane plant, particularly the stems and midribs of leaves, are prone to the attacks of *C. falcatum*. In the leaves the infection starts as a dark-red patch on the midrib. This patch elongates quickly and gives rise to blood-red lesions, provided with dark-coloured margins. In mature lesions, the central region becomes pale-yellow or straw-coloured. In the stems external symptoms are usually not visible until the disease has spread far internally. When the internal rotting of the stem is complete, the bright colour of the rind is lost, and shrinkage takes place at the nodes. The upper leaves of the infected plant become pale and droop down a little. At about this time their tips begin to wither. Subsequently, this withering begins to travel in a downward direction along both the margins, the central portion remaining unaffected and green. On splitting open an internally rotted stem, one or a few of the internodes, usually the basal ones, are noted to be red-coloured in longitudinal directions. Characteristically and crosswisely developed white patches interrupt these red striations. This

red colouration is extremely deep in the region of the vascular bundles. In the case of a serious attack the colour is found to be extending through a large number of internodes, and the entire crop withers and droops.

Though it is usually believed that the pathogen cannot persist in the soil, recently it has been investigated in India that it can do so upto a period of six months. Satisfactory evidences to prove it, however, are still lacking. At any rate, it has been observed that if sugarcane trash from infected plants be put in the soil, the fresh crop becomes largely infected.

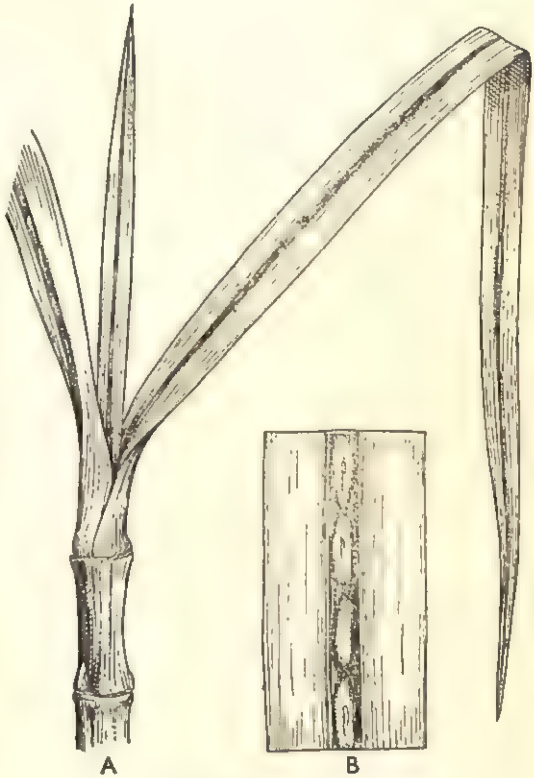

Fig. 213. *Colletotrichum.*
A, Part of a sugarcane plant infected with the pathogen; B, A portion of an infected leaf (magnified).

Vegetative body

The vegetative body of the pathogen is a mycelium, which is found mainly in the pith cells as well as in their intercellular spaces. The hyphae constituting the mycelium are septate, narrow, hyaline and extensively branched. The cells contain oil droplets.

Reproduction

C. falcatum reproduces by means of **conidia.** In the United States of America, however, the **perfect** or **ascigerous stage** has recently been discovered, both in the laboratory as well as in the field. This perfect stage is *Physalospora* sp. belonging to the Order Sphaeriales under the Ascomycetes.

In the shrunken up stems, in depressions or ridges just above or below the nodes, the **acervuli** appear on the rind as clusters of minute, velvety, dark-coloured bodies. These acervuli consist of long septate **setae** and a number of smaller-sized unseptate **conidiophores** bearing **conidia** singly near about the tips. The conidia are single-celled, hyaline but densely granular, usually falcate or sickle-shaped and guttulate. In some cases the setae develop forming a fringe around an acervulus. Occasionally, intercalary or terminal **chlamydospores** are found, which are greenish-black in colour. A conidium, on germination, either develops directly into a mycelium or gives rise to an **appresorium.** The conidia usually remain enclosed within the sheaths of the leaf-bases, where moisture is also retained. This helps in the germination of the conidia and when the leaves are torn off, innumerable scars are left behind at the nodes, through which the pathogen enters the host.

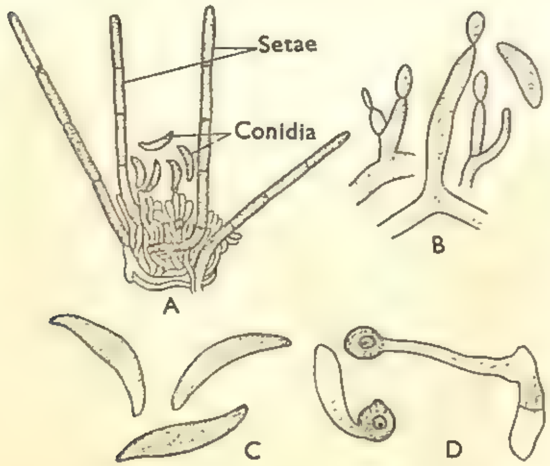

Fig. 214. *Colletotrichum.*
A, Part of an acervulus; B, Conidia being formed on conidiophores; C, Conidia; D, Germinating conidia forming appresoria.

Control measures

The use of healthy seeds, destruction of diseased plants and trash, improved cultural methods, and rotation of crops help in controlling the disease. The cultivation of red rot resistant varieties is, however, the most effective method in checking the disease.

Evolution and Degeneration of Sexuality in Fungi

It is the usual practice with the botanists to consider plants having definite sex organs and sexual reproductive units (gametes) as primitive ones and placed low in the scale of evolution than those which do not possess any apparent sex organs or gametes. The mode of sexual reproduction in fungi, in this respect, affords

a very good example of gradual reduction and final obliteration of any trace of the sex organs or gametes. If one gradually advances from the Phycomycetes to the Basidiomycetes through the Ascomycetes, one can never fail to notice it, though occasional types may be found, which shows a tendency towards the primitive forms. The different forms of sexuality found among fungi may be broadly summarized as follows.

ISOGAMY. This is the simplest and most primitive form of sexuality, found among lower Phycomycetes (e.g., *Synchytrium endobioticum*, *Olpidium vissiae*, etc.), in which sexual union takes place between two flagellated sexual cells, that are not closely related to each other, giving rise at first to a flagellated zygote. Since, the uniting gametes are morphologically identical with each other, they are called **isogametes.** These gametes always arise as daughter cells of the gametangia.

ANISOGAMY. This type of sexual union is exhibited by *Allomyces javanicus* in which the two uniting flagellated gametes differ only in size. They are also produced as daughter cells of the gametangia and the product of their union is always a zygote. Some mycologists hold that the larger gamete may be regarded as the female and the smaller, the male. The gametangium that gives rise to the female gamete is usually larger than the gametangium producing the male gamete.

OOGAMY. In this type of sexuality the gametes not only arise as daughter cells of the gametangia but they are sexually differentiated into male and female gametes. Typical oogamous reproduction is found in *Monoblepharis* where sexual union takes place between a flagellated small, motile male gamete or spermatozoid and a large, non-motile, non-flagellated female gamete or oosphere or ovum. The product of the union is always an oospore (zygote). The sexual organs are also differentiated into antheridium (male gametangium) and oogonium (female gametangium). In other cases, as in *Saprolegnia*, *Phytophthora*, *Pythium*, *Albugo*, etc., though the antheridia and oogonia become more marked and well-developed, the antheridium never gives rise to motile spermatozoids, which are represented by the male gamete nuclei. In such cases the male nuclei from the antheridium pass into the oogonium through the fertilization-tube and are discharged near the oosphere. Only one male nucleus then unites with the female nucleus of the ovum, and an oospore is formed. In *Saprolegnia* there are several oospheres

within the oogonium. In this case, several antheridia are formed and from these different fertilization-tubes penetrate the wall of the oogonium and discharge the sperm nuclei to the individual oospheres and fertilization takes place. As a result of union several oospores are produced within the single oogonium. The type of sexual reprodutction in which oospores are produced is known as **oomycetous,** and the group of fungi producing it is known as **Oomycetes.**

Gametangial copulation. This type of sexuality represents the first step towards the gradual reduction of sex in fungi. In this case the gamete formation is suppressed and union takes place between gametangia instead of gametes. The role of gametes is taken over by the gametangia, and as a result of gametangial fusion their multinucleate contents fuse to form a strong coenocytic zygote, known as the zygospore. Sexual reproduction resulting in zygospore formation is known as the **zygomycetous** type and the fungi forming zygospores are known as **Zygomycetes.** This type of sexuality is commonly found in *Mucor, Rhizopus, Phycomyces, Pilobolus,* etc. The species may be homothallic or heterothallic. In heterothallic forms the thalli as well as the gametangia produced by them are designated as (+) or female, and (—) or male.

Self-fertilization. This type of sexuality represents the next higher step towards reduction of sex in fungi and is found among the members of Ascomycetes. In this case only a functional oogonium is present, and an antheridium is either abortive or entirely absent. As a result, union cannot take place between two sex organs. There are two ways by which the sexual act is performed. In *Ascobolus citrinus* the female sexual organ is multicellular and union takes place between two cells of the female sexual organs (**parthenogamy**). In *Humaria granulata,* on the other hand, the oogonium is multinucleate and fusion takes place between the sexual nuclei in pairs within the oogonium and not by cell fusion (**autogamy**).

Pseudo-fertilization. In this case the degeneration in sexuality has gone a step further. The sex organs have completely disappeared and sexual union takes place between two vegetative cells. In many heterothallic Basidiomycetes (e.g., *Peniophora sambauci, Polyporus ostreiformis, Polystictus sanguineus, Polystictus hirsutus, Stereum fuscum, Lentinus subnudus,* etc.) fusion between the vegetative cells of mycelia bearing opposite sexual strains takes place and the

nuclei of complementary strains become associated together. In this case plasmogamy occurs and karyogamy is delayed till the formation of the basidium in which the two nuclei fuse to form a zygote nucleus. In some yeasts (e.g., *Saccharomyces*, *Zygosaccharomyces*, etc.) union takes place between two vegetative cells, the nuclei fuse and a zygote is formed. The uniting cells may be entirely unrelated or may be mother and daughter cells.

Parthenogenesis and Apogamy. These processes represent the last step in the reduction of sexuality in which reproduction takes place vegetatively without cell- or nuclear-fusion. In parthenogenesis new individuals are produced from haploid sexual cells, while in apogamy the individuals arise from diploid sexual cells withot t meiosis.

Heterothallism in Fungi

Heterothallism is a phenomenon which involves the interaction of two different kinds of thallus or strain for the formation of fruit bodies, the term fruit body being used in its widest sense. According to Gwynne-Vaughan and Barnes (1958), it is a "special instance of reaction to stimuli."

The phenomenon of heterothallism has been observed in the three groups of fungi, namely, Phycomycetes, Ascomycetes and Basidiomycetes. It is probable that heterothallism has arisen in each group independent of the other, but at the same time it may also suggest a remote connection between the Ascomycetes and the Basidiomycetes.

The segregation of sex occurs during meiosis, and the two sex factors contributed by the two parents are separated out leading to a reduction in chromosome number from $2n$ to n. In heterothallism a kind of stimulation takes place, when the two sex factors are brought into contact. As opposed to homothallic forms, the heterothallic ones can be considered as equivalent to the higher dioecious plants. The names of Blakeslee, Satina, Burgeff, Gwynne-Vaughan and others are associated with the study of heterothallism, and it is mainly through their efforts and researches that some light has been shed upon the problem.

The term heterothallism signifies that in a given species more than one gametophytic thalli or strains exist and that two of these must be compatible and come together to bring about the diploid condition. Those fungi which bear male and female reproductive

organs on different thallus bodies are also included in the same category.

The homothallic forms can reproduce sexually by means of hyphae bearing sex organs, produced on the same thallus. These hyphae are thus the products of germination of a single spore only. A few homothallic forms (e.g., *Absidia spinosa*), however, produce male and female gametangia of different sizes. This condition is termed as **heterogamic homothallism.**

Blakeslee (1904), while studying on Mucorales, described for the first time the existence of two different strains. He further noted that these heterothallic strains were morphologically similar, but differed in their physiological behaviours. It was rather difficult to distinguish between the male and female sexually uniting branches. So, instead of calling them as such, Blakeslee designated them as (+) and (−) strains. Shear and Dodge named the same as 'A' and 'B', while Tatum and Beadle preferred the terms 'A' and 'a'.

The only (+) and only (−) forms, when allowed to grow separately do not show any sexual reproduction. The distinctions that have been noted between the (+) and (−) strains are that the former exhibit a more luxuriant growth, especially on maltose medium, and can reduce the salts of *Tellurium* more readily than the latter.

Usually, the heterothallic species produce either (+) or (−) type of spores, but some Phycomycetes (e.g., *Phycomyces nitens*) produce both (+), and (−) and (±) types of spore in the zygosporangium.

Rapier observed a peculiar kind of heterothallism in *Achlya bisexualis*, where four different types of thallus are existing : (1) pure male thallus (purely heterothallic), (2) male thallus with a latent tendency of behaving like a female one (partially heterothallic); (3) pure female thallus (purely heterothallic); and (4) female thallus with a latent tendency of behaving like a male one (partially heterothallic). These four types, when growing independently, cannot exhibit any sexual reproduction. But if one of them grows in association with any one of the remaining three types, a sexual reproduction takes place. This peculiar phenomenon has been called **gynandromyotic heterothallism.**

Heterothallism has also been shown to exist among some other members of Phycomycetes, as in *Phytophthora* sp. (Ashley, 1928).

Heterothallism is of rare occurrence among the Ascomycetes, but some species have two different sexual strains. When these two strains are brought into contact, only then sexual organs are produced and a diploid condition is established. Such organisms are said to be **self-sterile** or **self-incompatible.** For example, *Ascobolus magnificus* possesses two strains A and B. Both of them can bear antheridia as well as oogonia. But, if they are grown separately, sex organs do not appear on them. On the other hand, when the mycelia of these two strains get intermingled, both of them produce antheridia and oogonia. The antheridia of A can fertilize the oogonia of B only, and *vice versa.* The zygote gives rise to spores of both the types.

In self-incompatible *Humaria granulata* antheridia are lacking in both A and B strains. The female branches, which appear in a single spore culture, die without forming any sporophyte. But, if complementary thalli are associated somehow with the culture, the female organ proceeds to the formation of asci, which bear both A and B spores. This shows that nuclei from both the thalli have entered the oogonium. This is an example of a case of mycelial fusion between complementary thalli. The asci of *Pleurospora tetrasperma*, *Podospora anserina*, etc., also show mycelial fusions, and their asci produce four binucleate ascospores, which ultimately give rise to homothallic or self-compatible mycelia.

A number of heterothallic species produce conidia. If these conidia can germinate in the vicinity of a mycelium of opposite strain they may bring about a sexual union between the two.

Glomerella singulata develops asci in single spore culture, but these are very poorly developed and contain only one type of spore, either A or B. When both the strains develop together in a mixed culture, numerous asci containing both the types of spore are produced. It is interesting to note that in *Penicillium luteum*, if the associated complementary strains are different in vigour, ascus-production is stopped.

The Basidiomycetes do not possess any sexual organ and the union between sexually compatible strain is achieved through mycelial fusion mainly. A dikaryotic mycelium is, as a rule, required for the production of a fruit body. In some special cases, however, a mycelium remaining in the primary condition for a long time may produce a fructification. Normally, the terminal cell of a dikaryotic hypha develops into a basidium, where the two nuclei undergo-

fusion, divide reductionally and form spores in sequence. Such hyphae are, thus, the secondary ones.

In those species, which are self-compatible the secondary mycelium arises from a single spore, while in self-incompatible species two complementary primary mycelia are needed for their formation of a secondary mycelium. In case of species with tetrapolar sex, there are four sexually different strains, AB, Ab, aB, and ab; the secondary mycelium can be developed only when AaBb condition is reached. Both in bipolar as well as in tetrapolar species in some cases, the formations of fruit bodies and the basidia may be delayed even when the mycelium is secondary until it comes in contact with a suitable primary one.

In the rusts, the stages of development in the formation of sporophyte are somewhat similar to those self-incompatible Ascomycetes. The flexuous hyphae and the detachable spermatia are found on the same thallus, but on account of their self-incompatibility cannot give rise to the sporophyte. The same can be achieved only when the spermatia of one sexual strain are brought into contact with flexuous hyphae of compatible opposite strain.

Extensive studies on the phenomenon of heterothallism have been made in the group of smut fungi by Stackman, Christiansen, Hanna, Dickenson and others. In this group the mature chlamydospore is uninucleate, with its nucleus having a $2n$ chromosome number. Meosis takes place during germination of the chlamydospore and subsequently each basidiospore possesses a haploid nucleus. These basidiospores have been shown to belong to two different categories sexually. Hanna has demonstrated that infection of a healthy maize plant by the corn smut fungus (*Ustilago zeae*) takes place through the agency of a haploid (monokaryotic) mycelium. When this monokaryotic mycelium accidentally comes in contact with another monokaryotic mycelium of suitable opposite sex within the host tissue diplodization occurs, and the mycelium becomes dikaryotic; but actual nuclear fusion takes place only inside a developing chlamydospore.

Economic importance of Fungi

The fungi are of great economic importance on account of their both harmful as well as beneficial effects. A large number of fungi cause destructive havoc to our valuable crop and timber plants, various kinds of food and food products. They also attack the live-

stock as well as the human beings. Some serious diseases of the skin, eye, ear, nose and throat as well as intestinal and bronchial disorders are also caused by the various groups of fungi. But, all of them are not harmful to the mankind, as most of the species bring about decomposition of dead bodies of plants and animals as well as of animal dung; thus the organic debris is removed from the surface of the earth and the fertility of the soil is enriched. Further, some species are edible and quite a good number of them produce various kinds of vitamins, organic acids, drugs, enzymes, alcohols and other medicinally and industrially important substances.

The Phycomycetes usually cause damage to different crop plants. For example, *Pythium de Baryanum* causes the 'damping off' disease resulting in the death of young seedlings. *Phytophthora infestans* is responsible for the serious 'late blight' and 'rot' of potato. *Albugo candida* brings about much deformation of the inflorescences and fruits of cruciferous plants throughout the world. *Peronospora parasitica* is the pathogen causing the 'downy mildew' of crucifers. *Saprolegnia parasitica* causes serious damage to the fishing industry. The various species of *Mucor* and *Rhizopus* spoil the preserved fruits, pickles, jams and jellies, bread, butter, cheese, leather and various other consumable articles. A few members of the Order Mucorales, however, can produce some organic acids.

Of the different ascomycetous fungi, the three medicinally most important ones are the yeasts, penicillia and ergot fungi. Various species of *Saccharomyces* are very good sources of vitamin B. *Penicillium notatum* and *P. chrysogenum* yield the wonder drug 'penicillin'. *Claviceps purpurea* produces the 'ergot', which is extensively used for stopping haemorrhage after child birth. The different types of yeasts are employed for the preparation of various kinds of alcoholic drinks as well as in baking breads. Some species of *Aspergillus* are used in the preparation of diastase and organic acids, while some costly cheeses are prepared with the help of a few species of *Penicillium*. *Morchella esculenta*, the common morel, is an edible fungus.

The polypores among the Basidiomycetes are the chief agents in causing serious damages to the timber trees, lumbers, railway sleepers, telegraph and fencing posts, and wooden buildings and furniture. It is interesting to note that some of them, however, are taken as food by man, such as *Daedalea flavida*. Besides various mushrooms puff balls also form table delicacies. Some of them are, however, deadly poisonous to the human system, and may even

cause death. The members of the orders Uredinales and Ustilaginales are highly destructive to the various important crop plants, like wheat, maize, oat, barley and others. Researches are going on for the discovery of antibiotics from some polypores. *Auricularia auricula* is locally used in some parts of India for curing ear sores.

Many of the Imperfect fungi not only cause diseases of some higher plants but also are responsible for the athletes foot, ringworm and other skin diseases in man.

CHAPTER III

THALLOPHYTA (*Contd.*)—MYXOMYCETES, SCHIZOMYCETES & LICHENS

MYXOMYCETES

The Myxomycetes or slime moulds occupy a dubious systematic position. As they show marked affinities with the Protozoa, some botanists favour their exclusion from the plant kingdom, while others consider that they occupy a position among the plants equal in status with the true fungi. They resemble the true fungi in the absence of chlorophyll as well as in the nature of reserve food materials, but they differ from them in having a single, large, naked, multinucleate amoeboid protoplast (**plasmodium** or **pseudo-plasmodium**).

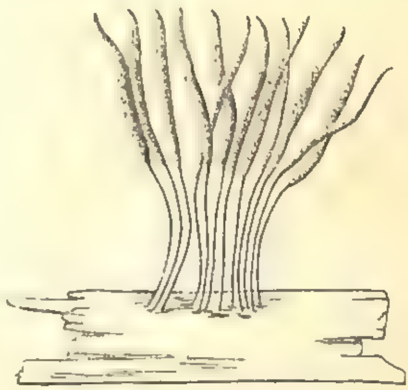

Fig. 215. *Myxomycetes.* Vegetative body of a plant.

The Myxomycetes are mainly terrestrial organisms, commonly found on fallen leaves, decaying wood, humus soil, etc. They are cosmopolitan in their distribution.

The free-living plasmodia of slime moulds look like gigantic amoeba and may be several centimetres in diameter. A plasmodium is capable of a creeping motion with the help of **pseudopodia,** which are finger-like protrusions developed from the body, and are alternately pushed out and withdrawn in succession. The vegetative body is multinucleate and cytoplasmic movements may be noted within it. Like amoeba it can also ingest solid food, such as spores, small remains of plant or animal bodies, bacteria and other microscopic organisms.

At the time of reproduction an entire plasmodium comes out of the substratum, forms a heap and gives rise to one or a few stalked or sessile **sporangia.** The sporangia are variously shaped. There is usually found a network of tube-like structures, called the **capilli-**

tium, within a sporangium, and numerous small **spores,** each surrounded by a wall of its own, are found in the meshes of the capillitium. On maturity, the sporangial wall ruptures and the spores are dispersed. Each spore, on germination, gives rise to 1-4 uniflagellate-like bodies, which may fuse in pairs immediately or undergo vegetative multiplication. If the swarmers unite in pairs, an amoeboid zygote is produced, which ultimately develops into a multinucleate plasmodium.

Fig. 216. *Myxomycetes.*
A portion of a plasmodium.

The Myxomycetes include about 50 genera and 400 species and are generally divided into two subclasses: (1) **Endosporeae,** where the spores are produced within the sporangium, and (2) **Exosporeae,** where the spores are borne externally on branched pillar-like structures. The former subclass consists of the following genera which are

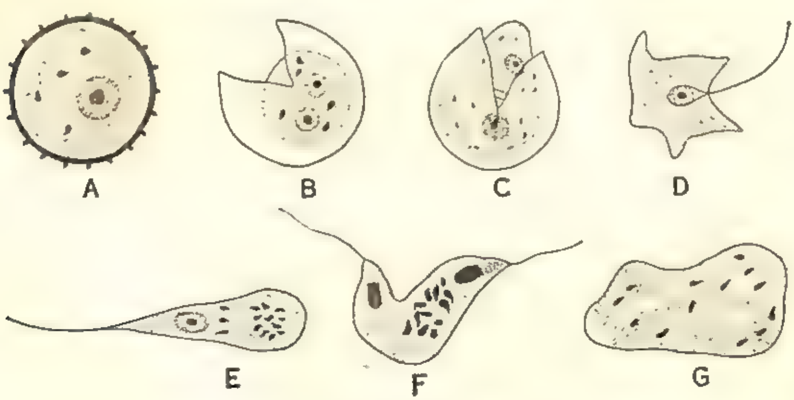

Fig. 217. *Myxomycetes.*
A, A mature spore; B—E, Germination of the spore and development of a swarmer; F, Two swarmers uniting; G, An amoeboid zygote.

found in India: *Physarum, Physarella, Trichemphara, Craterium, Diderma, Diachea, Didymium, Stemonites, Comatricha, Lamproderma, Cribraria,*

Lycogala, Trichia, Hemitrichia, Cornuvia, Arcyria, Perichaena, while the latter one is represented in India by the only genus *Ceratiomyxa.*

ORDER **PLASMODIOPHORALES**

PLASMODIOPHORA

(Fam. PLASMODIOPHORACEAE)

Plasmodiophora attacks a number of cultivated cruciferous plants. The best-known species is *P. brassicae*, which causes the **clubrot** or **finger-and-toe** disease of the cabbage.

The host may be attacked at any time during its active growth, but infection usually takes place at the seedling stage. The amount of moisture present in the soil is an important factor in the occurrence of the disease. The infection takes place when the soil contains about 60 per cent moisture or above, but not when the percentage falls to 45 per cent or below. Light soils and moorlands are also the favourite dwelling places of this pathogen than loamy and clayey soils. As the popular name suggests, the infection essentially takes place in the roots. A uniflagellate **swarmspore*** comes in contact with the cell wall of the root hair, loses its flagellum and then enters into the root hair in an amoeboid fashion. It may also directly penetrate into the older regions of the root cortex. The affected part begins to grow remarkably, and in the long run becomes abnormally swollen. When the disease is considerably advanced so as to cause a disturbance in the continuity of the vascular system, the leaves turn yellow, wilt and fall off, and the plant becomes stunted in growth.

Fig. 218. *Plasmodiophora.* Formation of the gall on tap root due to infection.

*Butler and Jones (1949) consider that the swarmspore is unequally biflagellate.

Vegetative body

The vegetative body is an intracellular multinucleate **plasmodium.**

Reproduction

Plasmodiophora reproduces both asexually and sexually.

Chupp (1917), and Cook and Schwartz (1930) are of opinion that the swarmspore, which causes the primary infection of the root, is a haploid body. The nucleus of the amoeboid cell, after it has entered into the root hair, divides repeatedly, and ultimately a multinucleate plasmodium is formed. Later on, the plasmodium breaks up into a number of uninucleate masses, each surrounded by a wall of its own.

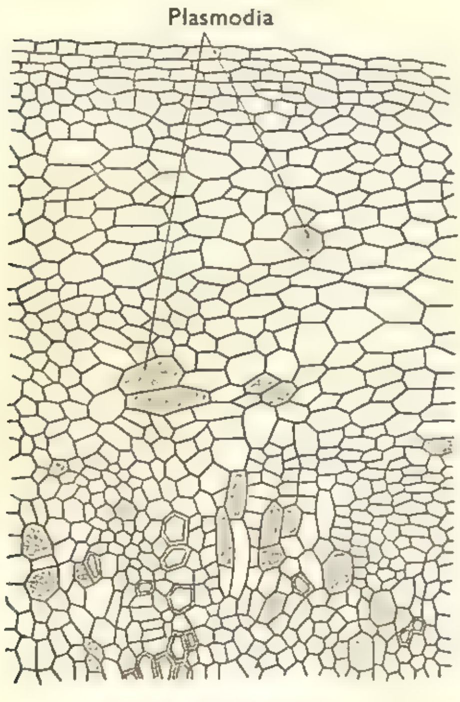

Fig. 219. *Plasmodiophora.* A portion of an infected root in transverse section showing the presence of plasmodia within certain cells.

During sexual reproduction each of these uninucleate cells, produced asexually, may develop into a **gametangium.** The gametangial nucleus again undergoes divisions forming four or eight nuclei. The cytoplasm is again cleaved, and each uninucleate mass is finally metamorphozed into a tiny, uniflagellate **zoogamete.** The zoogametes unite in pairs, either within the root hair itself, or after they have migrated into the neighbouring cortical cells. The product of fusion is an amoeboid zygote with one diploid nucleus. This zygote is known as the **myxamoeba.**

The myxamoeba then increases in size and its nucleus undergoes a few divisions, thus forming a diploid plasmodium. This plasmodium begins to migrate from one cell to another within the host tissue

and even comes inside the cambial cell. Vertical upward or downward migrating movements of the plasmodia through the cambium have been noted. Finally, when a plasmodium, after its outward migration, reaches a food-laden cortical cell it lodges within it, and increases considerably in size. Thus the swelling in the root is formed. Along with the increase in size of the plasmodium, its

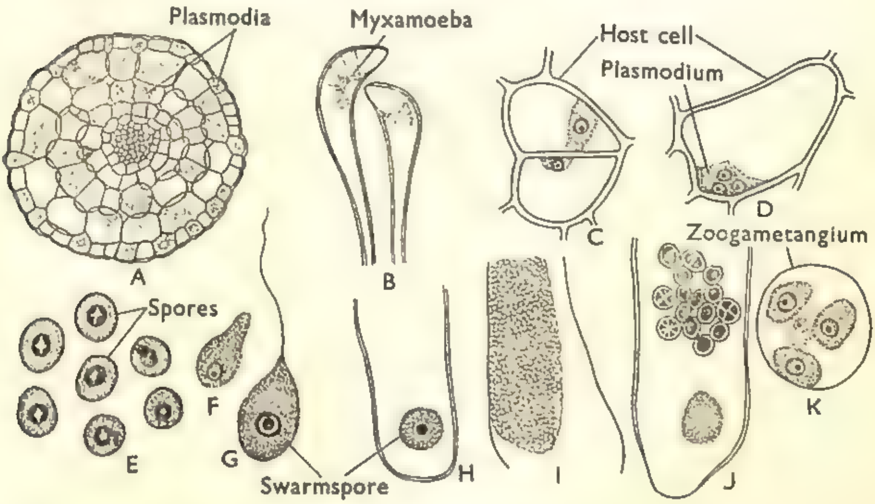

Fig. 220. *Plasmodiophora.*
A, T. S. of an infected root showing plasmodia; B, Myxamoebae within root hairs; C—D, Host cells with plasmodia; E, spores; F, A germinating spore; G, A swarmspore; H, A swarmspore (inside a root hair) with its flagellum withdrawn; I—J, Stages in the formation of zoogametangia; K, A zoogametangium containing developing zoogametes.

nuclei divide repeatedly, the last two series of divisions being meiotic (Lutman, 1913; Cook and Schwartz, 1930; Cook, 1933). When the nuclear divisions are complete, innumerable vacuoles of various sizes appear within the cytoplasm. Ultimately, the plasmodium is fragmented into many minute, uninucleate bits, each of which becomes a distinct **spore.** When the host undergoes degeneration, the spores are liberated as **swarmspores,** and fresh infections occur in the soil.

SCHIZOMYCETES (=BACTERIA*)

The Schizomycetes or bacteria are the simplest of all plants and

*The great German mycologist and plant pathologist Anton de Bary (1831-1888) excluded the bacteria from the fungi. Since then, the mycologists are unanimous in following de Bary's practice.

are present almost everywhere, in water, in air, in soil and in all organic bodies, living or dead. Some of them can withstand extreme heat and cold. Most of them live in the presence of oxygen and are said to be **aerobic,** but a few can live only in the absence of oxygen, when they are said to be **anaerobic;** others can live under both conditions.

Most bacteria either live saprophytically on dead organic matter, or parasitically on the living plants and animals. In very rare cases, bacteria live exclusively on living plants or animals, in which case they are said to be **obligate parasites.** Some bacteria are peculiar in their mode of nutrition. They obtain their energy from the oxidation of certain inorganic substances and from the fixation of nitrogen, etc. They are neither parasitic nor saprophytic and are said to be **autotrophic.**

Structure

Bacteria are usually unicellular, and the cell is very small in size, in extreme cases less than 0·2 micron* in diameter. The cell may be spherical, rod-shaped, or spiral. In a few cases cells are branched, and in some cases united together to form filaments. In many cases, many bacteria remain together in a mucilage forming the **zooglea stage.** Sometimes they are provided with delicate protoplasmic flagella. Each cell has a distinct cell wall which is neither of cellulose, nor of chitin. The protoplasm is homogeneous and is generally colourless, though occasionally it may contain pigments, such as green, red, blue, etc. A true nucleus is absent in bacterial cells. Chromatin granules are present in the cell and perhaps perform the function of the nucleus.

The unicellular bacteria are classified according to their shapes into the following types : **Cocci** are very minute and spherical in shape. They may remain singly or in pairs (**diplococcus**), or in regular groups of 4-8 (**sarcinae**). If two cells are surrounded by a common membrane, it is termed as the **capsulated diplococcus. Bacilli** are rod-like in shape. Many of them are provided with one or more flagella. Sometimes the rod may be curved and it looks like a comma; such a form is called a **comma bacillus. Spirilla** are coiled spirally.

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* 1 micron (1μ) = 1/1,000th of 1 mm.

Reproduction

Bacteria reproduce by vegetative, asexual and sexual methods.

During vegetative reproduction the bacteria commonly multiply by **fission** or **fragmentation.** A constriction appears in the middle of a cell, which gradually deepens and the cell is ultimately divided into two, which then usually separate.

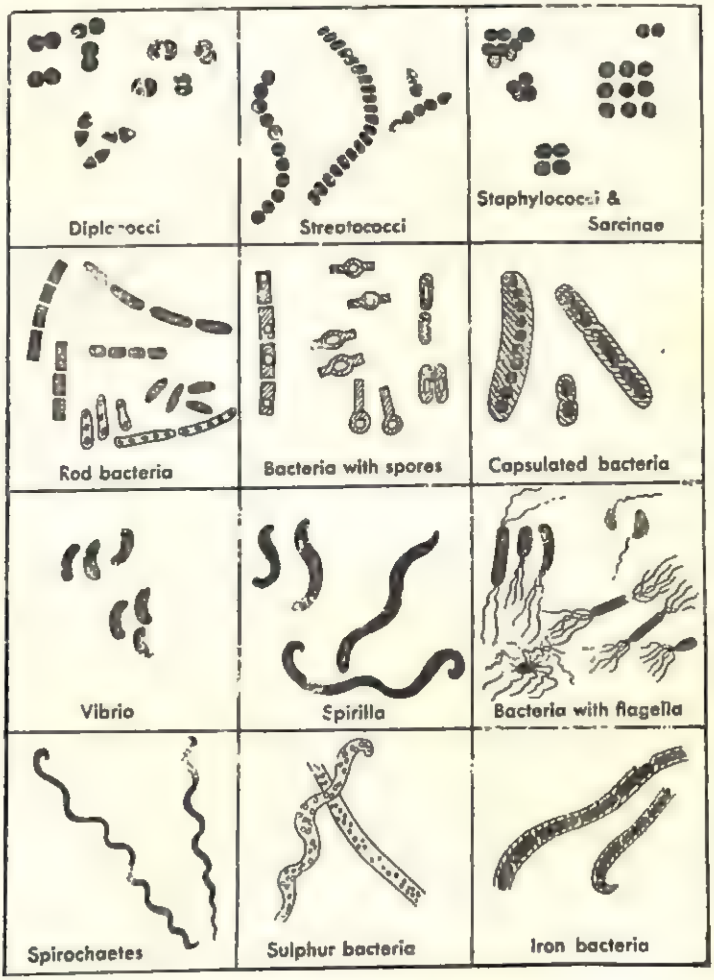

Fig. 221. Different types of *Bacteria.*

Many bacteria multiply asexually by means of **spores** and the process is known as **sporulation.** When the nutrient substance in the medium is exhausted, sporulation takes place. In the uni-

cellular forms, there is a contraction of the protoplast, which then surrounds itself with a wall, thus forming an **endospore** within the mother cell. These thick-walled spores are very resistive and can tide over the periods of drought, heat, cold, etc. When favourable conditions come, the wall of the parent cell bursts and the spore produces a bacterium. Reproduction in the higher forms takes place by means of **conidia.** The filamentous forms bud off conidia at their ends. These conidia are set free, and are sometimes motile and rod-shaped. The conidia, unlike the endospores, have no thick wall and are not resistive. After dispersal they settle and multiply by division.

Even a few years back, it was generally believed that the bacteria have got no sexual reproduction, reproducing only by vegetative or asexual means. But Laderberg and Tatum (1946) have clearly shown that in artificial cultures of some bacteria a few cells behave as gametes and unite in pairs to form a zygote. Further, the zygote produced by this process divides reductionally immediately and the haploid cells, thus produced, increase in number by simple somatic cell division. These races of bacteria are, therefore, haploid in nature, the diploid stage being restricted to the zygote only. Laderberg has, however, discovered a diploid race of bacteria, in which, as in higher organisms, a number of mitotic divisions intervene in between the formation of the zygote and its undergoing subsequent reduction division. It is rather very difficult to find out two conjugating bacterial cells in a colony under the microscope. Even if it so found, one should be careful about the following three possibilities : (*a*) the two cells might be in a conjugating process, (*b*) they might have been freshly formed by a division of pre-existing mother-cell, or (*c*) they have been by chance brought into a very close proximity. Consequently, sexuality in bacteria can be demonstrated more effectively by breeding experiments, rather than subjecting the different races to microscopical examinations. In this connection mention must be made of another race of bacteria, also discovered by Laderberg, where conjugation takes place between a distinctly flagellated cell and a non-flagellated one. Sexuality in bacteria was first demonstrated in the colon bacillus, *Escherischia coli.*

Economic importance of Bacteria

The bacteria are economically important, both for their harmful

as well as beneficial effects. If we consider both these effects, they will be found to be more helpful than harmful. In plants the bacteria cause different types of wilt, rot and cankar diseases. Some of them produce disease in animals causing serious epidemics in livestocks. They are also the cause of some fatal diseases like cholera, tuberculosis, diphtheria and others of human beings. Unscientifically canned foodstuffs may be attacked with bacteria and become poisoned, which may lead to death. *Bacillus denitrificans* is responsible for the denitrification of the soil, thereby making it poorer in its nitrogen content. On the other hand, genera like *Nitrosomonas*, *Nitrobacter*, *Azotobacter*, and *Rhizobium* help in adding nitrogen to the soil and thus increase its fertility. Different types of bacteria are utilized for various commercial and industrial purposes. They are used for the preparation of cheese, cream, butter, curd, vinegar, acetone, butyl alcohol and salt pickles. Bacteria are also helpful in the retting of fibres and in tanning. The leaves of tea and tobacco, after harvesting, are 'cured' and 'ripened' by employing different strains of bacteria for imparting particular types of flavour. Some actinomycetous bacteria yield valuable antibiotics like chloromycetin, aureomycin, streptomycin, terramycin and others.

LICHENS

Lichens are often popularly called as 'reindeer mosses'.

They grow in very varied habitats and are cosmopolitan in habit. In some cases they grow in such places, where it is practically impossible for other vegetations to thrive at all. Lichens are found to grow on the leaves of other plants, bark of trees, decaying logs, on the surface of soils and even on bare rocks, and are extremely drought-resistant.

Lichens are dorsiventrally differentiated thallophytic organisms consisting of two different types of plants, one of which is usually an alga and the other a fungus. The alga always remains enveloped by the fungus, and the two remain in such a close association that a lichen looks like a single plant. In the majority of cases the relationship between the two component organisms seems to be a symbiotic partnership. The fungus absorbs moisture from the substratum, while the alga prepares carbohydrates by photosynthesis. The algal partner may belong to the Myxophyceae

(usually *Nostoc, Stigonema, Rivularia, Gleocapsa,* etc.), or to the Chlorophyceae (e.g., *Protococcus, Cladophora, Trentepohlia,* etc.), while the fungal one is usually an ascomycete, exceptions being found in a few cases only, where it is a basidiomycete. The algal partner may lie uniformly distributed in the body of the thallus (**homoiomerous,** e.g., *Collema, Leptogium,* etc.) or it may be confined to a localized area below the upper cortex (**heteromerous,** e.g., *Parmelia, Usnea, Anzia,* etc.).

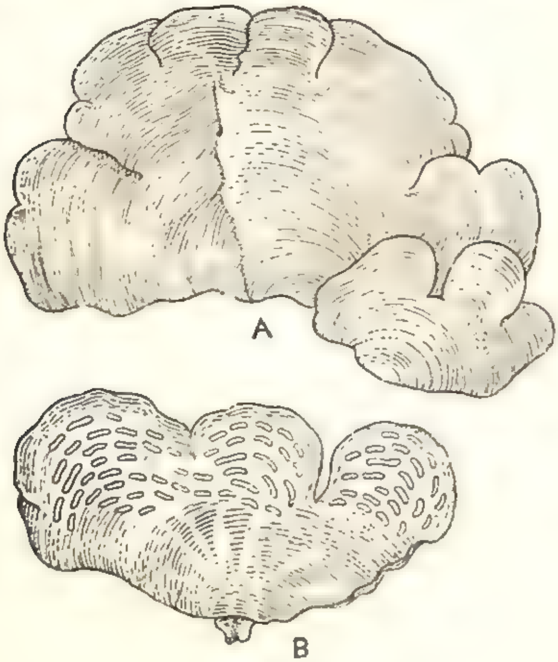

Fig. 222. *Basidiolichen.*
A, Dorsal view; B, Ventral view.

The Lichens are usually divided into *two* subclasses:

(*a*) **Ascolichens,** where the fungus is an ascomycete, and

(*b*) **basidiolichens,** where the fungus is a basidiomycete.

A few important Indian genera of lichens are cited below:

Dermatocarpon, Endocarpon, Tylophoron, Graphina, Collema, Leptogium, Lobaria, Rhizocarpon, Cladonia, Stereocaulon, Lecanora, Parmelia, Anzia, Ramalina, Usnea, Siphula, Physcia, Anaptyctia, Chaudhuria, etc.

Depending on the nature of the thallus, the Ascolichens may be:

(*a*) **Crustose.** In this type the thallus is crustaceous and adheres itself very closely to the substratum. In this type both the component partners (*i.e.,* the alga and the fungus) are uniformly distributed throughout a gelatinous or non-gelatinous body.

(*b*) **Foliose.** In this type the thallus is somewhat leaf-like in appearance, highly differentiated internally, and remains fixed to the substratum by means of rhizoid-like outgrowths (**rhizines**), which develop from the ventral surface of the thallus.

(*c*) **Fruticose** or **fructicose.** In this type the thallus is also

internally differentiated, much-branched, cylindrical to ribbon-like, and remains attached to the substratum by a distinct basal part, or may be erect or hanging.

Vegetative body

In most foliose lichens the thalli are internally differentiated into four distinct regions: (*a*) The uppermost region is known as the **upper cortex,** which is usually composed of vertical hyphae and may be bounded externally by a single layer of hyphae representing an epidermis-like structure. (*b*) Below this region is the

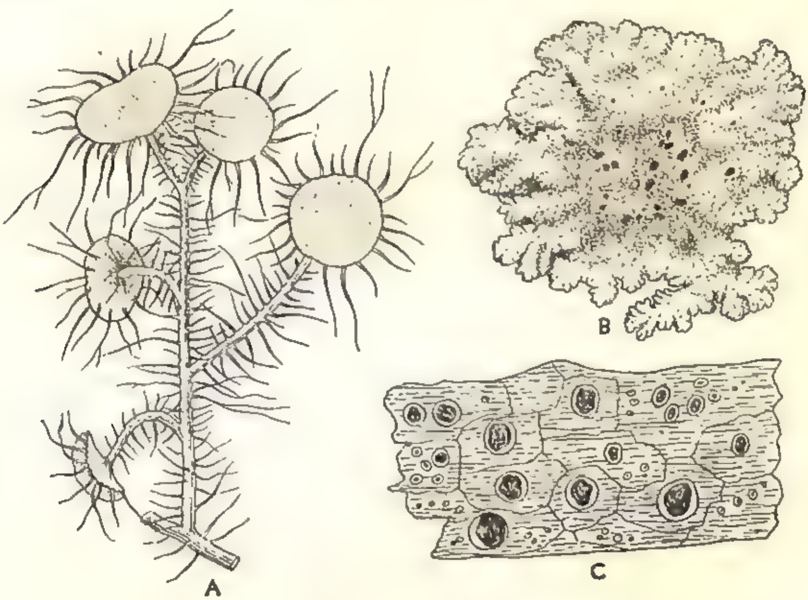

Fig. 223. *Ascolichens.*
A, Fruticose; B, Foliose; C, Crustose.

algal layer (also known as the **gonidial layer**) consisting of algae intermixed with loose hyphal elements. (*c*) The third layer is known as the **medulla,** which is made up of very loosely interwoven hyphae. (*d*) Beneath the medulla is the **lower cortex,** composed of highly compact hyphae, which are either perpendicular to the ventral surface of the thallus or are parallel to it. This region (the lower cortex) gives rise to the rhizoid-like outgrowths (**rhizines**) from its under surface.

Some foliose and fruticose lichens possess **breathing pores** in

their upper cortex, which help in the interchange of gases between the thallus and the external atmosphere. In some cases small

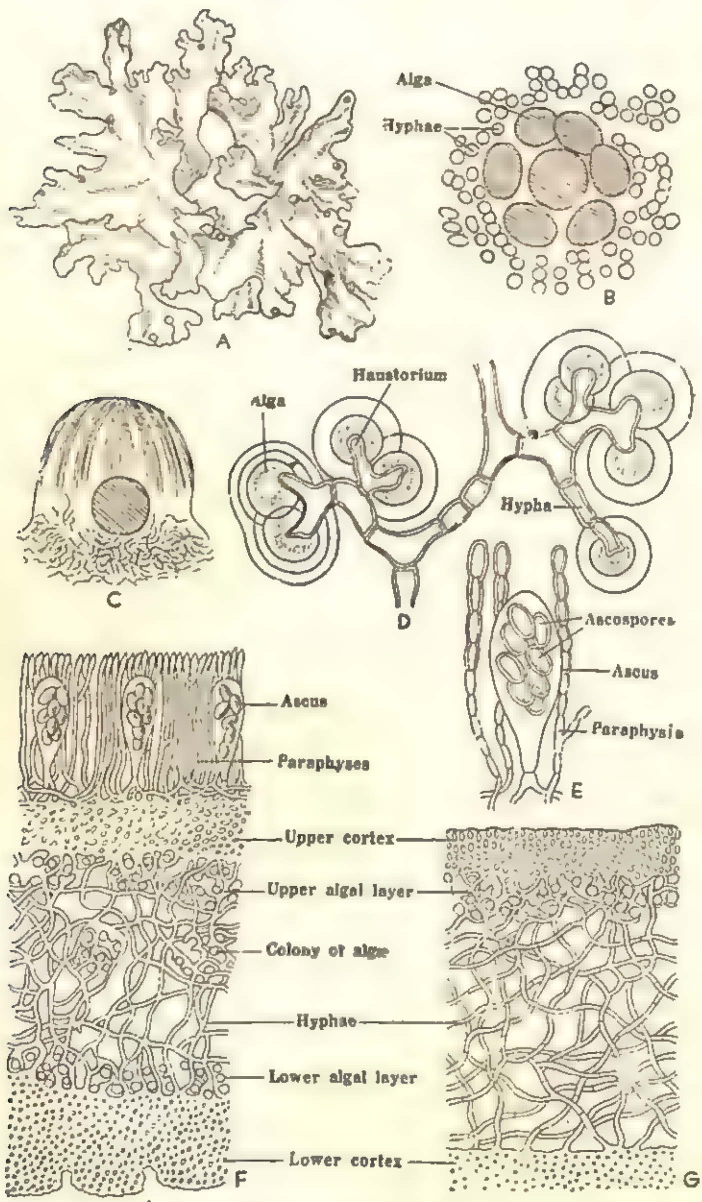

Fig. 224. *Ascolichen.*
A, A lichen; B—C, Successive stages in the development of soredia; D, Algal cells surrounded by fungal cells with haustoria; E, Ascus with ascospores and paraphyses; F, Section of apothecium; G, Section of thallus.

coral-like outgrowths, known as **isidia,** develop from the free surface of the thallus; these consist of an external cortical layer and an internal algal layer. Isidia help in photosynthesis and also function as vegetative reproductive bodies when detached from the thallus. Gall-like outgrowths, called **cephalodia,** containing both the algal and fungal elements, have also been found to be within or outside the body of the thallus of a lichen.

Reproduction

Lichens reproduce by vegetative, asexual and sexual methods.

Vegetative reproduction may take place by the fragmentation of a thallus, which contains both the symbionts. It also takes place with the help of **isidia** or by means of **soredia,** which are minute bud-like outgrowths developed on the dorsal surface of the thallus. A soredium consists of one or more algal cells enclosed by a few hyphae.

Asexual spores, like **oidia** or **pycnospores,** are regularly formed by the fungus of an ascolichen. These spores, falling on a suitable substratum, germinate very easily, and when the hyphae developed from them come in contact with the suitable alga, a lichen is produced. In some cases the alga of the lichen gives rise to typical **zoospores.**

The sexual reproductive organs, **spermogonia** and **ascogonia,** are always produced by the fungal constituent. The male reproductive organs, called the spermogonia, are flask-shaped cavities developed on the body of the thallus, which contain inside them numerous small male cells, called **spermatia.** The female organ, the ascogonium, is a multicellular structure, the lower part of which is spirally coiled and is known as the **archicarp;** the upper end is usually differentiated into a **trichogyne,** whose tip in most of the species projects slightly beyond the surface of the thallus. The spermatia become attached to the tips of the trichogyne and the contents of the spermatium pass into the trichogyne, but actual migration of the male nucleus has not yet been observed and practically nothing is known about nuclear fusion.

After fertilization, **ascogenous hyphae** are developed from the basal portion of the ascogonium, and finally an **ascocarp** (either an **apothecium,** when cup-shaped, or a **perithecium,** when flask-shaped) is produced containing many **asci** and **paraphyses.** Each ascus usually contains eight **ascospores.** Ascospores are

discharged in wet weather, and falling on suitable soil, germinate and give rise to hyphae. These hyphae coming in contact with suitable algae give rise to new lichens.

In some cases ascogenous hyphae are developed parthenogenetically without any formation of ascogonia.

Economic importance of Lichens

The economic importance of lichens is also well known. One of them yields a purple dye, which is used for staining purposes. Some of them containing oleo-resinous substances are used widely in the perfume industry. Some of the lichens are of pharmaceutical interest and some of them form the only fodder in the arctic regions for the reindeer.

CHAPTER IV

BRYOPHYTA

The Bryophytes comprise a small group of terrestrial plants which grow mostly in moist situations. They are more or less cosmopolitan in distribution and occur in all climates where there is plenty of moisture for the maintenance of life. They have a well-defined alternation of generations in their life cycles, and the sexual generation, or the **gametophyte,** *is always an independent plant* and carries on photosynthesis owing to the presence of chloroplasts in its body. The asexual generation, or the **sporophyte,** on the other hand, *is not an independent plant* but is always attached to the gametophyte, and is partially or wholly dependent on it for nutrition. The plant body is usually a thallus without any differentiation into roots, stems and leaves, but in higher forms it is differentiated especially into stems and leaves, though the roots are entirely absent. Instead, springing from the lower surface of the thallus or from the base of the stem, there arise a number of unicellular or multicellular filamentous structures, called **rhizoids** and **scales** respectively, which perform both the functions of absorption and fixation like the roots. All Bryophytes reproduce sexually by the process of fertilization. The sex organs, **antheridia** and **archegonia,** are *always multicellular structures* and the gametes, the **spermatozoids** and **ova,** are *always surrounded by an outer jacket of sterile cells.*

Origin of the Bryophyta

The botanists are almost unanimous in believing that the bryophytes have taken their origin from some green algae. Confirmation to this idea has recently been obtained from the works of Stroin (1948), who has shown that the pigments, chlorophylls and xanthophylls of the Chlorophyceae only, are identical with those found in the bryophytes. A few workers, like Haskall (1949), however, do not agree with this view and suggest that the bryophytes have been derived from the pteridophytes.

Previously, it was thought that an oogamous green alga, after its migration from water to land, gave rise to the sexual plant of a bryophyte, and simultaneously the phenomenon of alternation of

generations also appeared. But, as it has been found out that an alternation of generations takes place independently in various diverse groups of green algae, like Ulotrichales, Chaetophorales and Cladophorales, there is the possibility that the ancestral form might be isogamous as well.

Whatever might be the ancestral algal type, there are two opposite schools of view as regards the structure of the primitive gametophyte in bryophytes. According to one school (Von Wettstein, 1908; Kashyap, 1919; Church, 1919; Harris, 1938; and Evans, 1939), the primitive gametophyte was an erect leafy shoot. The other school (Cavers, 1910; Campbell, 1891, 1918, 1936) suggests that the gametophytic body was an undifferentiated thallus. The origin of the characteristic sex organs of bryophytes, however, presents some difficulty. The sex organs in the green algae are, as a rule, unicellular, and the majority of cells of a thallus can give rise to the gametes, while the sex organs of bryophytes are multicellular and the superficial cells constitute a sterile jacket of variable thickness. Davis (1903) put forward the hypothesis that both the sex organs, antheridia and archegonia, are fundamentally alike and evolved from a multicellular gametangium by gradual sterilization. According to this hypothesis, the hypothetical ancestral green alga bore superficially a number of multicellular gametangial outgrowths, more than one cell thick. At first, some of these outgrowths produced flagellate, motile male gametes, while the others produced similarly or dissimilarly sized, motile female gametes. Gradually, the cells in the surface layers began to fail to produce gametes and were converted into the sterile jacket. Those male outgrowths in which all the inner cells, excepting those of the jacket, retained their power of gamete-production, gave rise to the antheridia of the bryophytes. The bryophytic archegonium resulted by the complete sterilization of all the cells of the female outgrowths, excepting the lowermost as well as the innermost one, which lost its capacity to produce flagella and finally became an oosphere or egg.

As to the origin of the sporophyte in bryophytes, there are also two schools of view. According to the proponents of the **homologous (modification) theory** (Church, 1919; Zimmermann, 1932; and Fritsch, 1945), the sporophyte has evolved as a result of modification directly taking place in the gametophyte. According to these workers, both the gametophytic and sporophytic generations of the primitive bryophytes were externally complex, isomorphic,

free-living plant bodies. In course of time the sporophyte got attached to the gametophyte and began to depend upon it for a partial food supply. Consequently, the sporophyte became less complex in structure. Advocates of the **antithetic (intercalation) theory** (Anderson, 1923), however, believe that the sporophyte became gradually more and more complex from a simple one by progressive sterilization of the spore-producing tissue. They believe that the sporophyte is a completely new structure placed in between two successive sexual or gametophytic generations. According to them, the first primitive sporophyte appeared from the zygote, enclosed within the venter of the archegonium. This zygote, instead of undergoing a meiotic division, divided equationally and gave rise to a number of diploid cells, each of which in its turn, divided meiotically and produced four haploid spores. Thus, in such a sporophyte all the cells were sporogenous. Gradual evolution resulted in the formation of a sporophyte, whose superficial cells were sterile and non-sporogenous. As a result of further sterilization, the sporophytes of the more advanced bryophytes have become differentiated into distinct foot, seta, and capsule.

Evolution among the Bryophyta

Among bryophytes evolution appears to have taken place along three different lines,—Hepaticae, Anthocerotae and Musci. If the view of Campbell, and Cavers be accepted that the gametophyte of the most primitive bryophyte was a simple thallus body, then the simplest bryophytic gametophytes can be found among the family Sphaerocarpaceae of the liverworts (Hepaticae). The simplest sporophyte, on the other hand, will be found among the family Ricciaceae belonging to the same class. For this reason, Lotsy (1909) suggested an imaginary genus *Sphaero-riccia*, which was supposed to be the protobryophyte, the hypothetical ancestor of the present-day bryophytes.

Among the Hepaticae the Sphaerocarpales appear to be most primitive, with which the Marchantiales are related to some extent. The Orders Jungermanniales and Calobryales, which are considered both as advanced as well as the most primitive by different workers, are rather remotely connected with the other groups of hepatics. Some workers believe that the leafy hepatics (Jungermanniales and Calobryales) have give rise to the true mosses. But taking the question of ontogeny of sex organs and the early developmental

stage of the embryo into consideration, it seems more likely that the true mosses appeared quite independently of the hepatics. Both the classes Hepaticae and Musci, however, appear to be blind side lines from the evolutionary standpoint of view. On account of similarities existing in the structure of gametophytes as well as in the ontogeny of sex organs, it seems that the Anthcerotae might have originated and departed very early from some primitive Hepaticae. Further, due to the indeterminate growth of its sporophyte, the anthocerotes are supposed by some workers to have given rise to the pteridophytes.

Classification of the Bryophyta

The Bryophytes have been divided into the following *three* Classes :

Class I. Hepaticae. The Hepaticae have dorsiventrally differentiated gametophytes, which are either externally simple (e.g., *Riccia* and *Marchantia*) or differentiated into stems and leaves (e.g., *Jungermannia*). Internally, they may be homogeneous or composed of different kinds of tissues. Sex organs are always formed on the dorsal surface of the thallus. The sporophytes may be extremely simple (e.g., *Riccia*) or differentiated into foot, seta and capsule (e.g., *Marchantia*) and these are always entirely parasitic upon the gametophytes for nourishment.

Class II. Anthocerotae. The gametophytes of the Anthocerotae have distinct dorsiventrality and are of simple external forms. The internal construction is homogeneous. The sex organs are developed on the dorsal surface and are embedded into the tissue of the thallus. The sporophytes are differentiated into capsule and foot. The lower part of the capsule, corresponding to the position of the seta, is highly meristematic. The sporogenous tissue is developed from the **amphithecium** instead of from the **endothecium,** which is transformed into **columella.**

Class III. Musci. The gametophytes of the Musci have a transitory prostrate stage bearing radially symmetrical, leafy, sexual branches, which continue to grow as independent plants after the disappearance of the prostrate portion. Sex organs are developed near about the tips of the sexual branches and are produced either on the same plant (**monoecious**) or on different plants (**dioecious**). The sporophytes are differentiated into foot, seta and capsule and are semi-parasitic upon the gametophytes for nourishment.

CLASS I. HEPATICAE

Hepaticae has been divided into 4 Orders by Smith (1938, '55) incorporating the suggestions of Cavers (1910) and Campbell (1936): (1) **Sphaerocarpales,** e.g., *Sphaerocarpus*, (2) **Marchantiales,** e.g., *Riccia, Marchantia*, (3) **Jungermanniales,** e.g., *Lejeunea, Pellia, Porella*, etc., and (4) **Calobryales,** e.g., *Calobrya.*

ORDER 2. MARCHANTIALES

The gametophyte is differentiated into a prostrate, ribbon-shaped, dorsiventral and dichotomously branched structure. Except in a few genera, air chambers are present on the dorsal surface of the thallus. The ventral surface bears scales and rhizoids. The rhizoids may be smooth-walled or pegged. Members of this Order have archegonia with six vertical tiers of neck cells.

The sporophyte may be very simple representing a spore case (e.g., *Riccia*) or may be differentiated into foot, seta and capsule (e.g., *Marchantia*). However, the capsule never contains elaterophores and there is no well-developed definite mechanism for the dehiscence of the capsule. The sterile jacket of the capsule is always one cell in thickness.

The Order Marchantiales has been divided into *five* families by Smith (1938, '55): (a) **Ricciaceae,** (b) **Corsiniaceae,** (c) **Targioniaceae,** (d) **Monocleaceae***, and (e) **Marchantiaceae.**

RICCIA

(Fam. Ricciaceae)

Riccia, a common liverwort, grows usually during the rainy season on damp walls, moist places, etc., in dense patches, or rarely in pools of water as free-floating scum.

There are more than 125 species of *Riccia* distributed throughout the world, all are terrestrial, but only one species is aquatic, viz., *R. fluitans*. The most commonly occurring Indian species is *R. discolor* (= *R. himalayansis*).

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* Verdoon (1932) and Evans (1939) do not include Monocleaceae in the Marchantiales.

The gametophyte

The vegetative body of each plant is a flat, dorsiventral thallus, wholly prostrate and typically rosette-like. It branches dichotomously. Each branch of the thallus is wedge-shaped and thickened on the middle line. On the ventral side of the thallus, there are numerous scale-like structures, one-cell in thickness, and many rhizoids which perform the function of the root. Rhizoids are of two kinds, smooth-walled and pegged, i.e., with various types of ingrowths of the wall projecting into the lumen of the rhizoids.

Fig. 225. Gametophytic thallus of *Riccia*.

When a transverse section of the thallus of *Riccia* is examined under the microscope it is found that the upper or dorsal portion consists of vertical tiers of cells containing chloroplasts, while the lower or ventral part is a tissue of colourless parenchyma cells, which may contain starch. There is a single row of canals, extending throughout the entire length of the chlorophyll-bearing tissue; these canals are the air chambers. The air chambers are perfectly smooth and are without any ingrowths. At the top of the air chambers there is the so-called 'epidermis', which is only one cell in thickness. The air-pores are simple unicellular spaces bounded by several 'epidermal' cells. In older portions of the thallus and on the vertical surface are observed the unicellular rhizoids lying between the multicellular scales.

Reproduction

Riccia reproduces both by vegetative and sexual methods.

Vegetative reproduction takes place in five ways: (*a*) by the progressive growth of the apical region, followed by death and decay of the older portion; as a result of decay, the two lobes of the dichotomy are ultimately separated and each of them develops into an independent plant, (*b*) by the formation of adventitious branches, developed from the ventral surface of the thallus, (*c*) by the growth of the surviving apical cell of the thallus of the previous

season, (*d*) by the formation of tubers developed from the thallus, and (*e*) by the development of gemmae-like bodies from the rhizoid-tips; these bodies detach themselves from the parent thallus and give rise to new individuals.

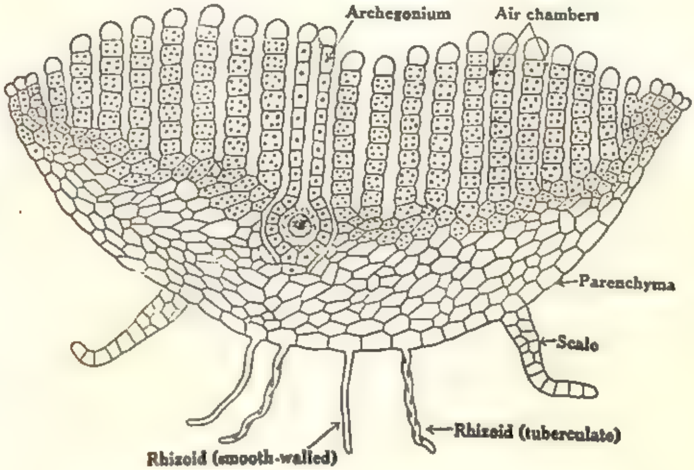


Fig. 226. Transverse section of the thallus of *Riccia*.

Most species of *Riccia* are monoecious, i.e., antheridia and archegonia are borne on the same plant, but a few are dioecious, i.e., with antheridia and archegonia being borne on different plants. The sex organs are borne in acropetal succession in a more or less linear row within the longitudinal furrow on the dorsal side of the vegetative body.

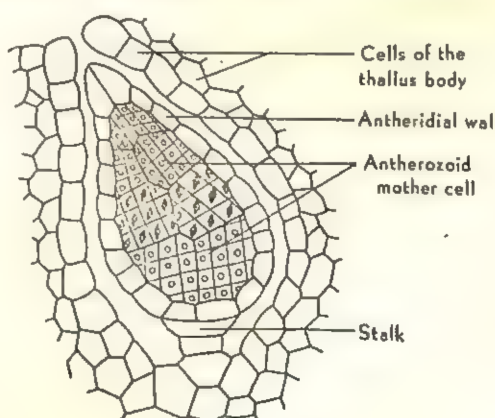


Fig. 227. *Riccia*. Vertical section through a mature antheridium.

Antheridia occur in discoid areas above the general level of the thallus. Each antheridium is completely enclosed in an antheridial chamber formed by the growth of the adjacent tissues and connected to the exterior by a narrow slit-

like opening. Each antheridium is a pear-shaped body, stalked at the broader end. It is surrounded by a single layer of sterile cells at the exterior, forming the wall of the antheridium. Enclosed by this wall, there are numerous cells, each with a relatively large nucleus and dense cytoplasm. These are antherozoid mother-cells or sperm mother-cells. Each mother-cell undergoes a single nuclear division and by an oblique partition forms two cells, each of which is metamorphozed into a single biflagellate **antherozoid** or **spermatozoid.** When the spermatozoids mature, there is a complete dissolution of the cell walls within the antheridium, so that the spermatozoids lie in a common cavity and are ultimately discharged.

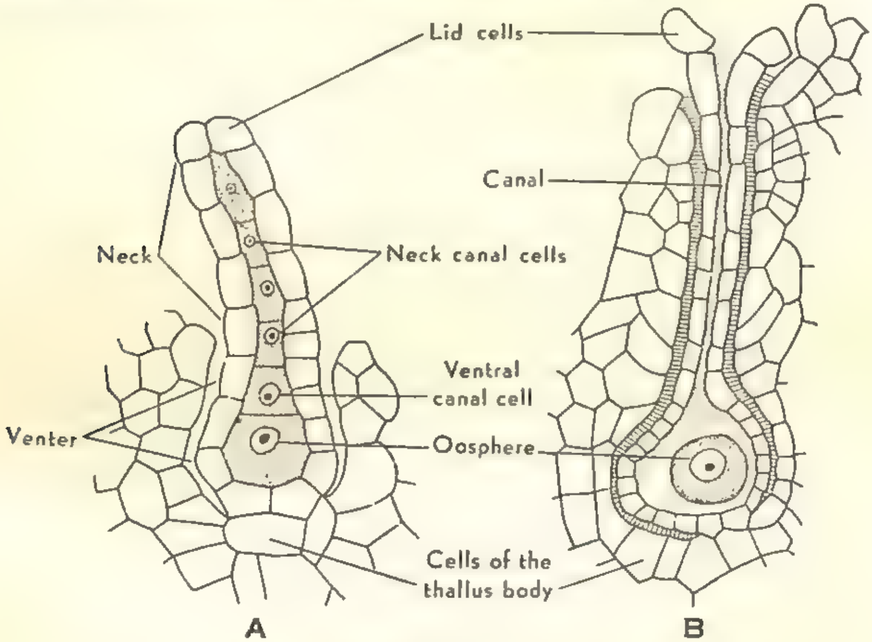


Fig. 228. *Riccia.*
A, A mature archegonium; B, An archegonium ready for fertilization.

Archegonia lie in the deep pits or furrows and are partially enclosed by the overgrowth of the surrounding tissues. Each archegonium is a flask-shaped body with a very short stalk and consists of two parts: an enlarged basal portion, called the **venter,** and an elongated, comparatively large, tubular portion known as the **neck.** The venter consists of **ventral canal cells** and a large **oosphere** or **ovum** or **egg,** and the neck consists of a number of **neck canal cells.**

When the archegonium matures, there is a complete dissolution of the canal cells, so that a passage is established. Biflagellate spermatozoids enter into the venter, one of which eventually fertilizes the egg. The fertilized ovum is then surrounded by a thin cellulose wall and becomes an **oospore.** *With fertilization and formation of the oospore, the sporophytic or diploid generation begins.*

The sporophyte

The oospore, as soon as formed, increases in size until the venter of the archegonium is almost completely filled up, and then undergoes a single division to form a two-celled **embryo.** This embryo by the process of repeated cell divisions grows into a multicellular structure, many times larger than the zygote in size. The sporophyte, when consists of 20-30 cells, becomes differentiated into an outer layer of sterile cells, called the **amphithecium,** and an inner mass of fertile sporogenous cells, known as the **endothecium.** Meanwhile, the venter also increases in size, and the entire sporophyte remains enclosed within the gametophytic tissue. Each cell of the endothecium, consisting of a relatively large nucleus and dense cytoplasm, is a **spore mother-cell.** The spore mother-cells undergo contraction of protoplast. The disintegration of the walls of the sterile cells, except the wall of the venter, results in a viscous fluid in which the spore mother-cells remain suspended. Each one of them then undergoes reduction division and forms **spores.** The spores, when mature, have a wall of three layers and they are liberated by the death and decay of the surrounding tissues. *With reduc-*

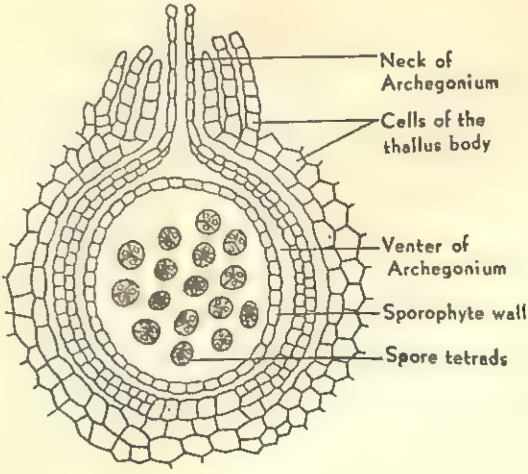


Fig. 229. *Riccia.*
Transverse section through a newly mature sporophyte with spore tetrads.

tion division and formation of spores, the gametophytic or haploid generation begins.

The new gametophyte

Spores, at the advent of favourable conditions, germinate ; the two outer walls burst and the innermost wall produces to form a germ tube which ultimately forms a new gametophyte.

MARCHANTIA

(Fam. MARCHANTIACEAE)

Marchantia, a common liverwort, is generally found on moist soils, rocks, etc. There are about 65 species of *Marchantia* distributed throughout the world. Of the 4 species, *M. palmata*, *M. nepalensis*, *M. simlana* and *M. polymorpha* growing in India, the last-named one is very common and practically speaking it is cosmopolitan in distribution.

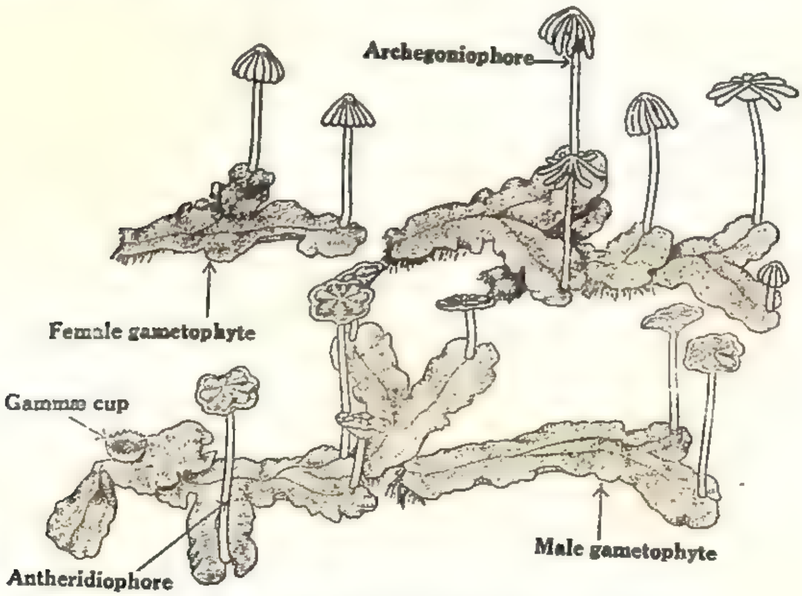


Fig. 230. *Marchantia*.
Thallus with antheridiophores and archegoniophores.

The gametophyte

The thallus is found creeping on the surface of the substratum in

the form of a rosette and is closely attached to it by means of rhizoids found on the under surface of the thallus. The branching of the thallus is dichotomous and there is a prominent midrib.

In transverse section of the thallus, it shows an upper epidermis which contains many air-pores which open to the external surface. Beneath the upper epidermis lies the air chamber containing branched filaments of cells, which grow upwards from the layer of cells composing the floor of the chamber. The cells of these fila-

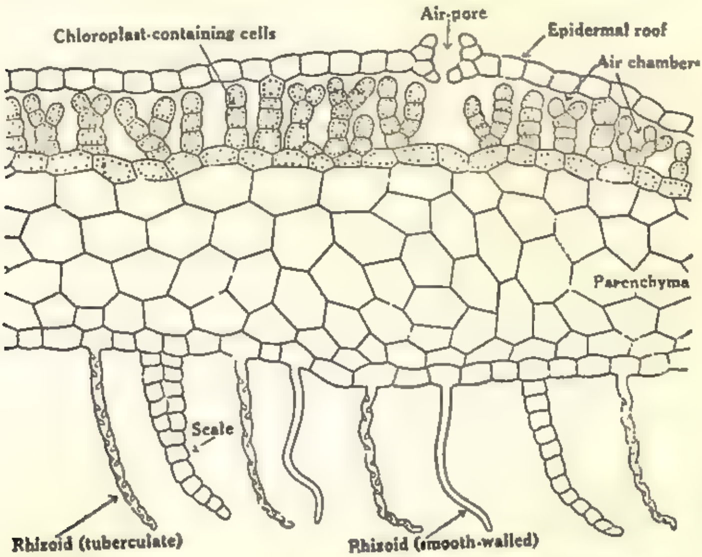


Fig. 231. Transverse section of the thallus of *Marchantia*.

ments contain chloroplasts and constitute the main photosynthetic tissue of the plant. Beneath the air chambers there are several layers of cells containing a few chloroplasts. From the lower surface of the thallus grow scales and rhizoids. The rhizoids are of two different kinds: some are simple, others are pegged, the inner surface of the walls of which are marked by localized thickenings.

Reproduction

Marchantia reproduces both by vegetative and sexual methods.

The vegetative multiplication takes place by apical growth and branching, and by progressive death of the older parts of the thallus due to which the number of plants is increased. It also

takes place by the formation of lens-shaped structures (**gemmae**) which are produced in a great number in shallow cups known as

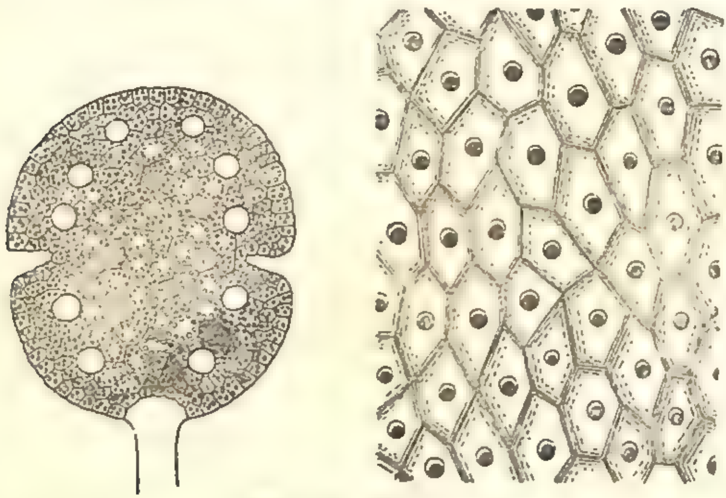


Fig. 232. *Marchantia.*
Thallus with gemmae cups containing gemmae; an enlarged view of one of which is shown on the left hand side.

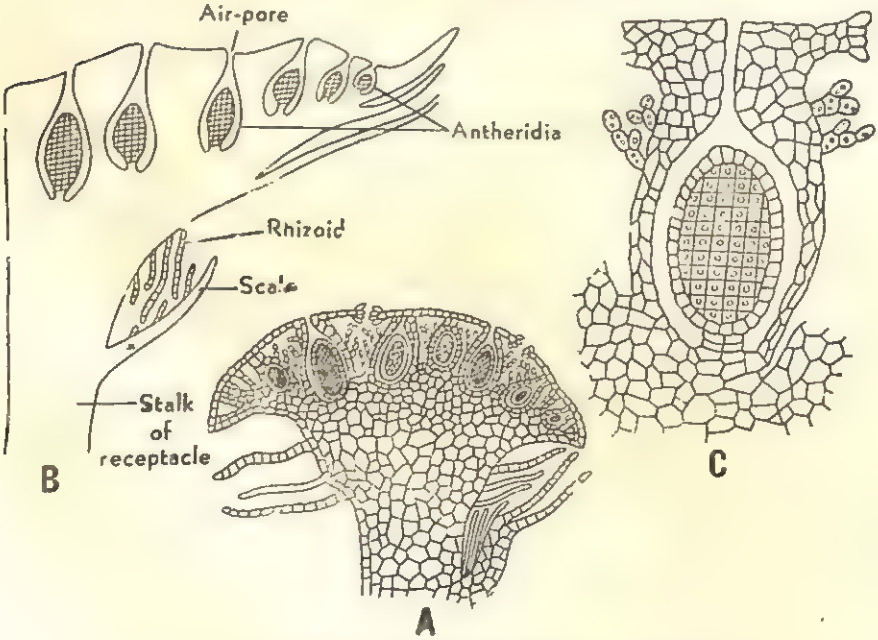


Fig. 233. *Marchantia.*
A, A v.s. of the disc of a male branch showing the position of the antheridia; B, Diagrammatic representation of half of the same; C, A v.s. through a mature antheridium.

gemmae cups. Each gemma is attached to the thallus by means of a one-celled stalk, from which the gemma is easily detached. Each gemma is more or less round with two notches in the middle and when it falls on the substratum, cell divisions begin at the notches and two plants are consequently formed.

The sex organs of *Marchantia* are borne on special erect branches, each composed of a stalk and a terminal horizontal disc. The male and female branches may be borne on the same plant (monoecious) or on different plants (dioecious).

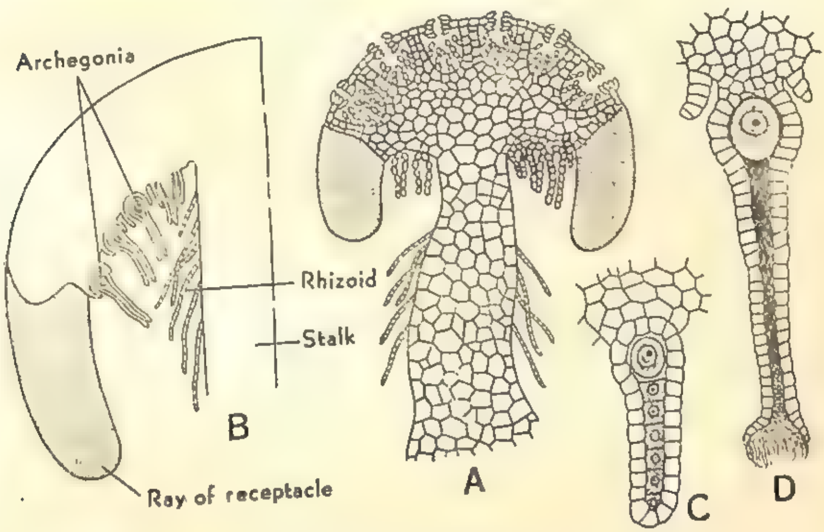


Fig. 234. *Marchantia.*
A, A v.s. of a female receptacle showing the position of the inverted archegonia; B, Diagrammatic representation of half of the same; C, A young archegonium; D, A mature archegonium ready for fertilization.

The disc borne by a male branch (**antheridiophore**) is lobed and the **antheridia** are embedded on the upper surface of each lobe. The oldest antheridium is found at the centre and the youngest towards the outer extremity of the lobe. There are air chambers with pores between the cavities containing antheridia. When ripe, the wall of the antheridium ruptures and numerous biflagellate spermatozoids or antherozoids are liberated in a drop of water.

The female receptacle borne on a female branch (**archegoniophore** or **carpocephalum**) is divided into rays, and the **archegonia** at first develop on the upper surface, but due to growth of

the central part of the upper side of the disc, the archegonia become inverted with neck downwards, the youngest archegonium is found towards the centre and the oldest one towards the extremity of the ray. Each archegonium has a long narrow neck with many neck canal cells and a swollen venter with a ventral canal cell and an egg.

Fertilization takes place in presence of water. The spermatozoids enter into the venter through the neck of the archegonium, the neck canal cells having been disorganized before fertilization. One of the spermatozoids eventually fertilizes the egg. The fertilized egg is surrounded by a thin cellulose wall and becomes an **oospore.** *With fertilization and formation of oospore, the sporophytic or diploid generation begins.*

The sporophyte

The oospore develops immediately into a sporophyte within the venter of the archegonium. When fully developed, it is differentiated into (*i*) a broad basal **foot,** (*ii*) an elongated stalk or **seta,** and (*iii*) a terminal **capsule.**

As a result of fertilization, the ventral cells of the archegonium are stimulated to divide and re-divide forming a tissue, known as **calyptra,** which surrounds the developing sporophyte till the latter attains maturity. Some of the cells at the base of the archegonium also divide and form a cylindrical sheet-like outgrowth, known as **pseudoperianth,** surrounding the archegonial venter with its enclosed sporophyte. The oospore, first divides transversely into two cells—an upper and a lower. The second division is, however, at right angles to the first, so that a four-celled embryo is formed. The two uppermost cells, the **epibasal cells,** by division and re-division give rise to the capsule and the upper part of the seta, and the two lowermost cells, the **hypobasal cells,** by subsequent divisions form the lower part of the seta and the foot. The foot is a broad, expanded tissue which fixes the sporophyte to the gametophyte and absorbs water and nutrient solutions from it. The seta consists of vertical rows of more or less isodiametric cells, which, during the later part of the development of the sporophyte, elongates considerably. Due to the elongation of the seta, the calyptra ruptures and the capsule is pushed outwards beyond the pseudoperianth. Early in the development of the embryonic sporophyte its capsule portion is differentiated into an outer **amphithecium**

and an inner **endothecium.** The amphithecium remains one-celled in thickness and forms the outer covering, or outer **jacket** layer, of the capsule. The first cell generation of the endothecium is the **archesporium,** which divides and re-divides to form a mass of **sporogenous tissue.** A few apical cells of this tissue remain sterile, while others elongate and divide obliquely. Finally, half of

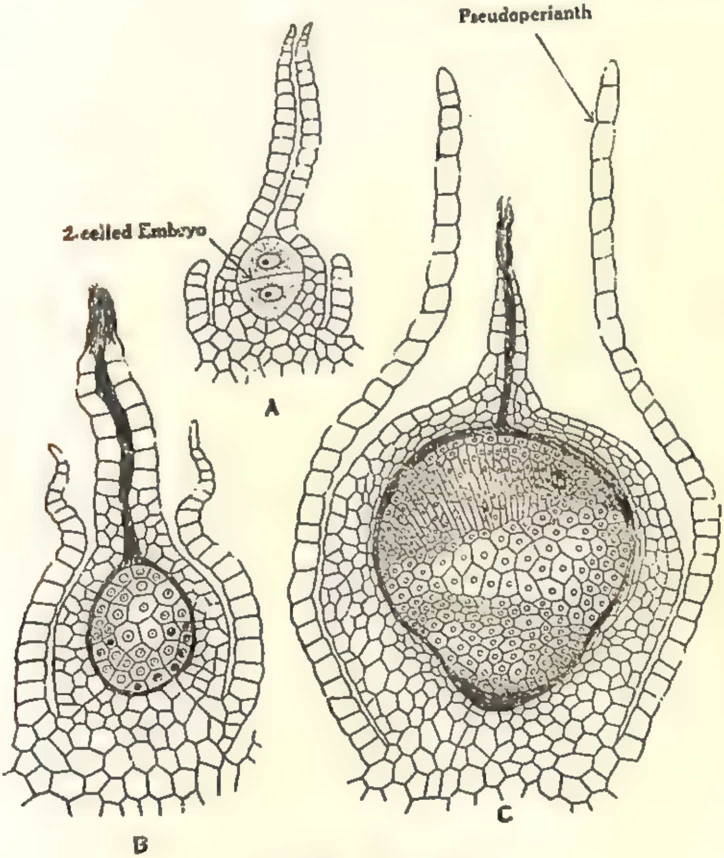


Fig. 235. *Marchantia.*
A—C. Successive stages in the development of the sporophyte.

the sporogenous cells, by two or three successive divisions, gives rise to more or less isodiametric spore mother-cells. The other half of the sporogenous cells becomes much elongated, each with two spiral thickenings on its wall, and forms the **elaters.** The spore mother-cells and elaters are usually evenly distributed within the wall of

the capsule. Each spore mother-cell by reduction division forms four **spores.** *With reduction division and formation of spores, the gametophytic or haploid generation begins.*

At maturity, when the capsule is pushed outwards beyond the pseudoperianth due to the sudden increase in length of seta, the jacket of the capsule splits up from the apex to about the middle into an indefinite number of segments and the spores are liberated. During the process the elaters coil and uncoil due to hygroscopic changes in their walls and assist in the liberation of spores.

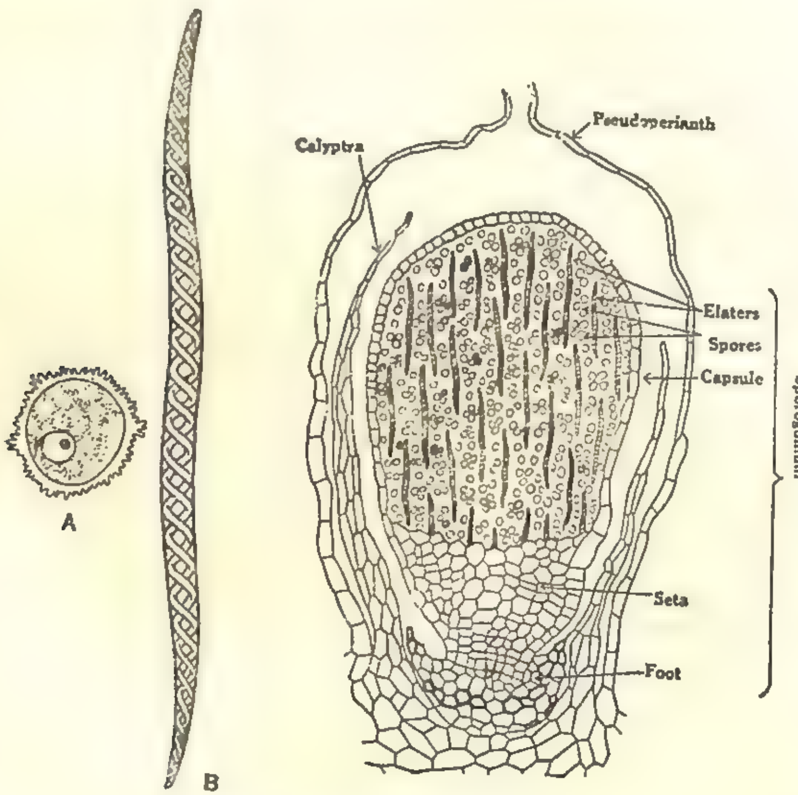


Fig. 236. *Marchantia.*
Longitudinal section of the sporogonium;
A, A spore; B, An elater.

The new gametophyte

The spores, after liberation, are dispersed and carried away by the wind. Each spore under suitable conditions germinates,

increases considerably in size, divides to form a six- to eight-celled irregular filament (protonema), from which a typical gametophytic thallus is gradually differentiated.

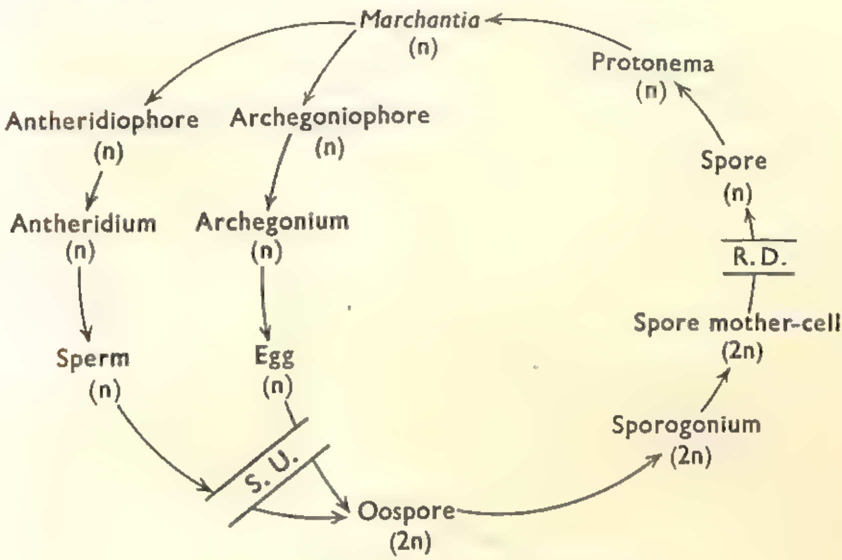


Fig. 237. Life cycle of *Marchantia*

ORDER 3. JUNGERMANNIALES

The gametophyte may be thallose or foliose, or intermediate between the two. In no case, an air chamber is found in the gametophyte, and little internal differentiation is noticeable. The gametophyte bears smooth-walled rhizoids and mucilagenous hairs, but neither any scale nor any pegged rhizoid. The members of this Order have archegonia with five vertical rows of neck cells.

The sporophyte is always differentiated into foot, seta and capsule. The jacket of the capsule is usually more than one cell in thickness. The capsule always contains elaters and these may form a columnar structure, the **elaterophore,** which may be attached to the apex or to the base of the capsule. The capsule has a well-defined mechanism for dehiscence, and it splits up into four definite valves.

Smith (1938, '55) includes two suborders under the Order Jungermanniales: (*a*) **Metzgerineae** (**Anacrogynae**), and (*b*) **Jungermannineae** (**Acrogynae**).

SUBORDER METZGERINEAE (ANACROGYNAE)

The gametophyte is dorsiventral, and generally thallose, more rarely foliose in form. In this suborder the apical cell never develops into an archegonium and consequently, the mature sporophyte is never terminal, but is situated on the dorsal surface of the thallus a little behind the apex.

Verdoorn (1932) includes *seven* families under the suborder: (*a*) **Treubiaceae,** (*b*) **Codoniaceae,** (*c*) **Haplolaenaceae,** (*d*) **Monocleaceae*** (*e*) **Dilaenaceae,** (*f*) **Metzgeriaceae** and (*g*) **Aneuraceae**†.

PELLIA

(Fam. PELLIACEAE‡)

Pellia, a thallose member of the leafy liverworts, grows on moist soil, rocks and among mosses and grasses forming green or dark-green patches. It may also grow in running water.

There are 3 species of *Pellia* reported to be found in India—*P. epiphylla*, *P. fabbroniana* and *P. neesiana*.

The gametophyte

The gametophyte is a simple, green, dorsiventral and dichotomously or pinnately branched structure. The thallus is externally differentiated into a **midrib** and **lateral wings,** the latter constituting the chief photosynthetic organs of the plant. The margins of the wings are undulated. On the ventral surface are present several smooth-walled rhizoids and a few mucilagenous hairs.

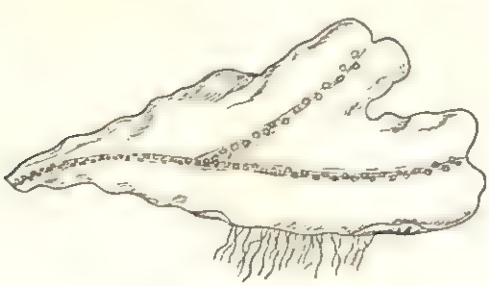


Fig. 238. *Pellia*.
A gametophytic thallus.

The internal structure of the gametophyte is very simple. It is mainly made up of parenchyma cells. The midrib portion is several cells in thickness, while the margins gradually become one

* Smith includes the family Monocleaceae with the Order Marchantiales.
† Richardiaceae of Smith.
‡ Haplolaenaceae of Verdoorn.

cell in thickness. The cells of the wing and the superficial cells of the midrib contain chloroplasts, and practically all the cells contain starch grains.

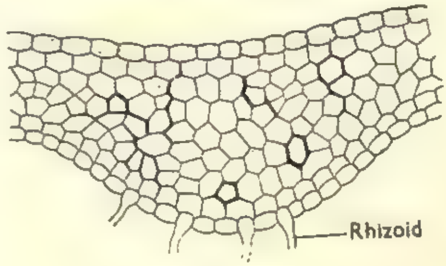


Fig. 239. *Pellia.* T.S. of thallus.

Reproduction

Pellia reproduces both by vegetative and sexual methods.

Vegetative reproduction takes place by three different ways: (*a*) by the progressive growth of the thallus and subsequent death and decay of the older regions, (*b*) by multicellular **gemmae** formed from the superficial cells of the thallus, and (*c*) by the formation of underground **tubers.**

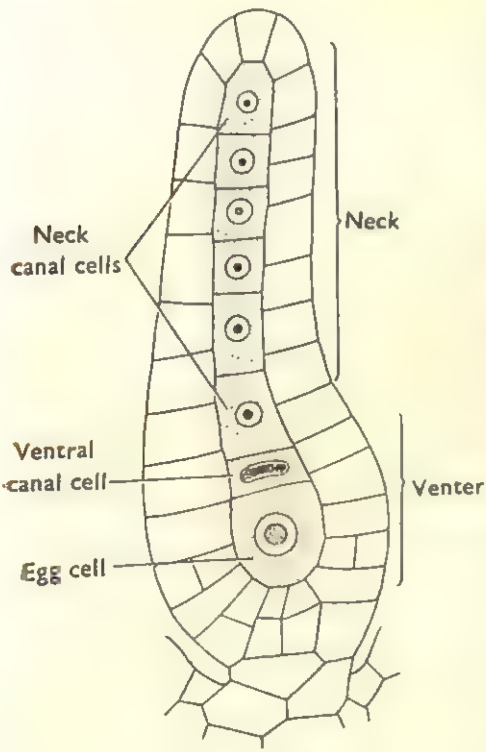


Fig. 240. *Pellia.* An archegonium.

The plant is either monoecious or dioecious. The sex organs are borne dorsally on the midrib in two or more distinct rows. In homothallic species, antheridia are borne behind the archegonial clusters.

The **antheridia** develop from the superficial dorsal cells close to the apical cell. A mature antheridium is globose or subglobose with a short stalk and a jacket, one cell in thickness. The antheridia are slightly embedded in the tissue of the gametophytes. At maturity they burst suddenly, thereby liberating the relatively large biflagellate antherozoids.

The **archegonia** also

develop from the superficial cells on the dorsal side. The archegonium initials, which give rise to the archegonia, lie very close to the apical cell, but unlike *Porella*, the apical cell itself never develops into an archegonium. The archegonia grow in clusters in pit-like depressions and are surrounded by an **involucre.** A mature archegonium has a venter and a neck. The neck is not very sharply delimited from the venter. The wall of the venter and that of the basal part of the neck become two-celled thick before fertilization. The wall of the neck is composed of five vertical tiers of cells. The neck contains 4-6 neck canal cells and the venter contains a solitary ventral canal cell and an egg.

Fertilization takes place in presence of water. The antherozoids swim into the venter through the passage formed by the disintegration of the neck canal and ventral canal cells. But only one antherozoid enters into archegonium and fertilizes the egg. The fertilized egg surrounds itself by a wall and forms the **oospore.** *With fertilization and formation of oospore, the sporophytic or diploid generation begins.*

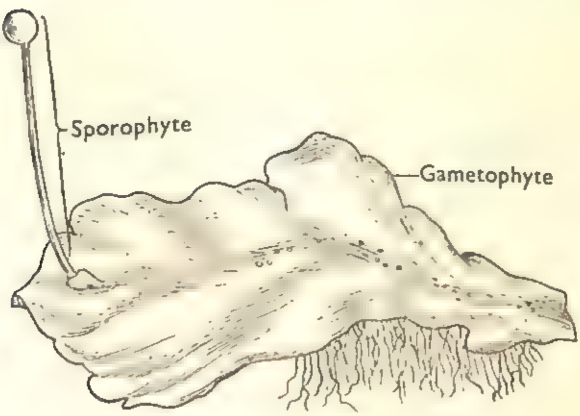


Fig. 241. *Pellia.*
A gametophyte with attached sporophyte.

The sporophyte

The oospore enlarges filling the cavity of the venter. The venter by subsequent development forms the calyptra. Within each involucre, a single **sporogonium** (sporophyte) is developed and the remaining archegonia become abortive.

The oospore, by a transverse wall, forms a **hypobasal cell** and an **epibasal cell.** The hypobasal cell undergoes no further division but forms an **haustorium.** The sporogonium is wholly developed from the epibasal cell. The epibasal cell undergoes transverse divisions and from its four upper cells develop the capsule, while from the lower four develop the seta and the foot.

Within the capsule, by division, two regions are set apart, an outer wall of two layers of cells and an inner multi-layered mass. From the latter (endothecium) develops the sporogenous tissue and the sterile **elaters.** The elaters are long, slender with double spiral thickenings on their walls. Some of the sterile cells become compact at the base of the capsule and form the **elaterophore.** The

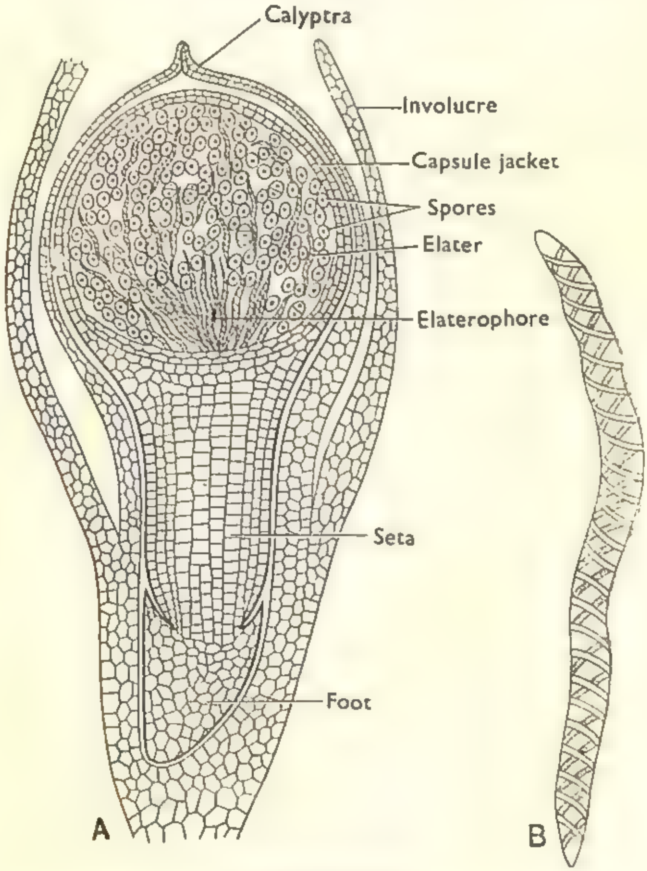


Fig. 242. *Pellia.*
A, V.S. through a mature sporogonium; B, A single elater (magnified).

spore mother-cells, by meiotic division, form the **spore tetrads.** *With reduction division and formation of spores, the gametophytic or haploid generation begins.*

The mature capsule is globose. It has an outer jacket consisting of two or more layers of cells. The outer layer has cells with rod-like

thickenings on their radial walls. The sporogonium of *Pellia* requires about a year, after fertilization, for its complete development. The jacket of the mature capsule has four vertical rows of thin-walled cells which indicate the lines of dehiscence.

The new gametophyte

In *Pellia*, the spores germinate while they still remain inside the capsule. Each spore forms a small, few-celled, ellipsoidal structure containing chloroplasts. These are set free in the cavity of the capsule by the disintegration of the spore wall. Finally, they are liberated by the dehiscence of the capsule. The elaters and the elaterophore aid in the dehiscence of the capsule and also for the discharge of the spores. The spores, on falling upon a suitable substratum, germinate giving rise to new gametophytes.

SUBORDER JUNGERMANNINEAE (ACROGYNAE)

The gametophyte is generally foliose, more rarely thallose in form. In every case, the **gametophores** (the shoots which bear sex organs) are differentiated into stems and leaves. The leaves may be present in two lateral rows only, or in two lateral as well as in one ventral rows. The leaves of the lateral sides are known as **lateral leaves** and those on the ventral side are known as **ventral leaves*** or **amphigastria.**

In this suborder the apical cell develops into an archegonium, and as such, the mature sporophyte is always terminal in position.

Verdoorn (1932) includes 14 families under this suborder: (*a*) **Haplomitriaceae,** (*b*) **Macvicariaceae,** (*c*) **Epigonanthaceae,** (*d*) **Scapaniaceae,** (*e*) **Schistochilaceae,** (*f*) **Chephaloziellaceae,** (*g*) **Trigonanthaceae,** (*h*) **Ptilidiaceae,** (*i*) **Pleuroziaceae,** (*j*) **Goebeliellaceae,** (*k*) **Radulaceae,** (*l*) **Porellaceae,** (*m*) **Lejeuneaceae,** and (*n*) **Frullaniaceae.**

PORELLA (=MADOTHECA)

(Fam. PORELLACEAE = MADOTHECACEAE)

Porella, often termed as 'leafy liverwort', grows on rocks and

* These are also known as **under leaves.**

barks of trees forming light-green or brownish green patches. The genus consists of about 180 species, found both in the tropical as well as in the temperate regions. In India there are about 34 species mainly found in the Himalayas, of which the important ones are *P. decurrents, P. obtusifolia* and *P. platiphylla*.

The gametophyte

The gametophyte is a prostrate structure which is differentiated into the stem and leaves. The stem is pinnately branched with leaves arranged in three rows, two dorsal and one ventral. The dorsal rows form the lateral leaves, while the ventral row forms the **amphigastria** or under leaves. Each lateral leaf is unequally bilobed. In some epiphytic species, the under leaf is modified into a water sac. The arrangement of the lateral leaves is **incubous***, since they are obliquely inserted on the stem in such a way, so that the lower leaf overlaps the margin of the succeeding upper one on the dorsal surface. The lateral leaves are chlorophyllous and form the photosynthetic organs. Smooth-walled rhizoids are developed from the ventral surface of the stem and branches, and fix the plant to the substratum. It is to be noted that where bran-

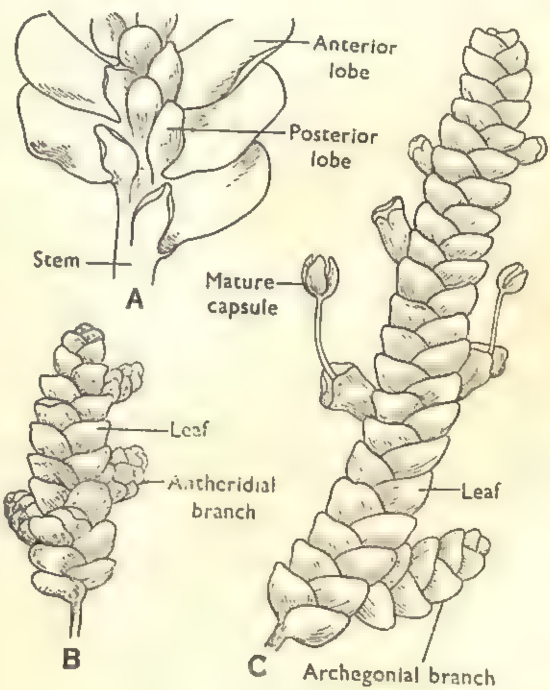


Fig. 243. *Porella*.
A, A portion of the vegetative body; B, Same with antheridial branches; C, Same bearing archegonial branches and mature capsules.

* In a **succubous** type of arrangement, the mode of overlapping is reversed.

ching takes place, the branches replace the lower lobes of the lateral leaves.

There is but little internal differentiation of the tissues of the thallus. All the cells of the gametophyte are parenchymatous. Air chambers and mucilagenous cavities are entirely absent.

Reproduction

Porella reproduces both by vegetative and sexual methods.

Vegetative reproduction takes place by three different ways: (*a*) by the progressive growth of the thallus and subsequent death and decay of the older parts, (*b*) by the formation of adventitious branches, and (*c*) by the production of one- or two-celled **gemmae** from the leaf-margins.

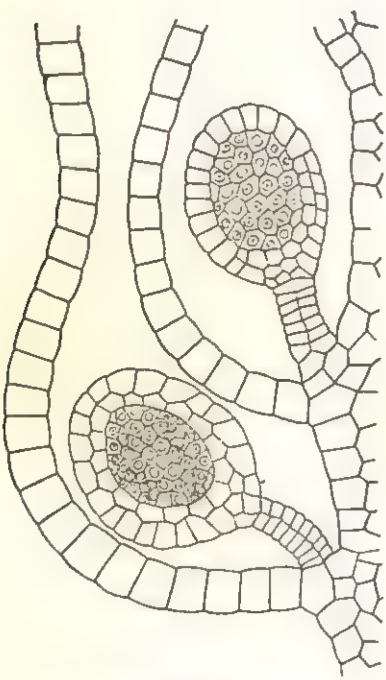


Fig. 244. *Porella*. Portion of an antheridial branch bearing antheridia in the axils of leaves.

The plants are either monoecious or dioecious, and the sex organs are borne on short lateral branches together with the bracts.

Each **antheridium** is borne in the axil of a leaf of an antheridial branch. A mature antheridium is more or less globose with a long stalk. The jacket of the antheridium is one cell in thickness except at the apical region. Antherozoids are typically biflagellate and crescent-shaped.

The archegonial branches are shorter than those of the antheridial ones and bear archegonia at their apices in groups. They are surrounded by a rosette of modified enlarged leaves. An archegonium develops from the apical cell, thereby checking further growth of the branch.

A mature **archegonium** has a broad venter containing a ventral canal cell and an egg. The wall of the venter is more than one cell in thickness. The neck is long and contain 6-8 neck canal

cells. Each group of mature archegonia is surrounded by a thin sheath developed from the archegonial branch. This sheath is termed as **marsupium.**

The gametic union requires the presence of sufficient water. The antherozoids are carried by the current of water near the archegonium, one of which ultimately unites with the egg, thereby, effecting fertilization. *With fertilization and formation of oospore, sporophytic or diploid generation begins.*

Fig. 245. *Porella.* A single antherozoid.

The sporophyte

The oospore, produced as a result of fertilization, divides transversely into a **hypobasal cell** and an **epibasal cell.** The hypobasal cell produces an **haustorium** of two or more cells. The rest of the sporophyte develops entirely from the epibasal cell.

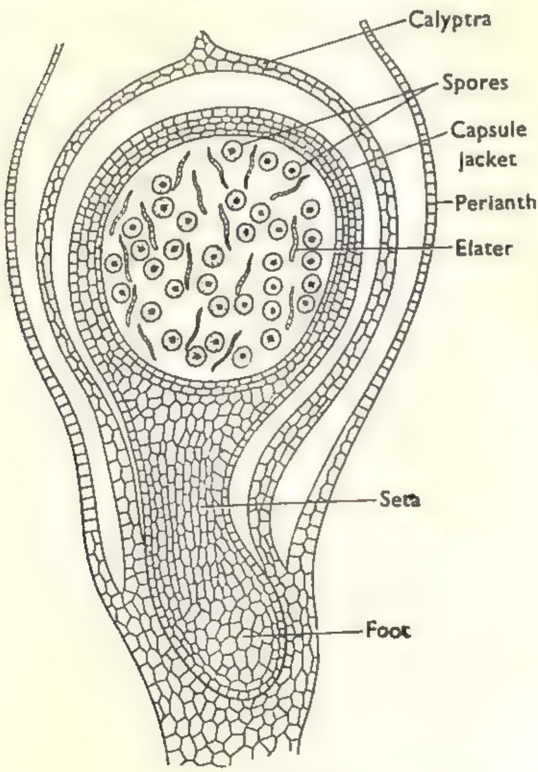


Fig. 246. *Porella.* V.S. through a mature sporogonium.

A mature sporophyte has a **foot,** a **seta** and a **capsule.** The foot is bulbous, the seta is short and the capsule is large and globose. The jacket of the capsule is more than one cell in thickness. The cells of the outermost layer are thick-walled, except along the four vertical lines which form the future lines of dehiscence of the capsule. The jacket develops

from the amphithecium. The endothecium forms the sporogenous tissue. Certain portion of the sporogenous tissue is fertile and by reduction division forms the **spore tetrads,** while the rest are sterile and develop into **elaters.** The spores may be brown or golden brown in colour and in many cases, they may be winged. *With reduction division and formation of spores, the gametophytic or haploid generation begins.* The elaters may be branched or unbranched.

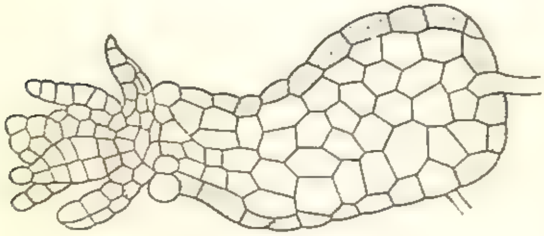


Fig. 247. *Porella.*
A newly-formed gametophyte.

A mature sporophyte is protected by the **marsupium, perianth** (formed by the bracts of the archegonium) and the multi-layered **calyptra** (formed from the venter).

The mature capsule, prior to dehiscence, is carried up beyond the calyptra, perianth and marsupium by the sudden elongation of the seta. The capsule then splits from apex downwards along the four vertical lines of dehiscence. The dehiscence is mainly due to the hygroscopic movements of the elaters.

The new gametophyte

The spores, falling upon suitable substratum, germinate to produce new gametophytes.

LEJEUNEA

(Fam. Lejeuneaceae)

Lejeunea, a member of the leafy liverworts, is generally found on moist shady barks of old trees but sometimes it also grows on rocks, or on moist walls associated with mosses.

Of the 7 Indian species, only two, viz., *L. chinensis* and *L. perrottetii* have been identified.

The gametophyte

The gametophytes of *Lejeunea* vary greatly in size. They may be

minute and delicate, medium-sized, or large and robust. They are always foliose, differentiated into stem and leaves.

The branching of the stem is pinnate (alternate) and not dichotomous. When very young, the whorled leaves are in three vertical rows, but due to differential growth, leaves of the mature stem are alternately arranged and obliquely or almost longitudinally inserted. The bilobed leaves have their margins entire, or more or less toothed. The amphigastrias may be entire, or bifid, or rarely absent (e.g., *Lejeunea* sp. E).

The internal structure of the gametophyte is very simple and has but little differentiation of tissues. The rhizoids are all of the smooth-walled type.

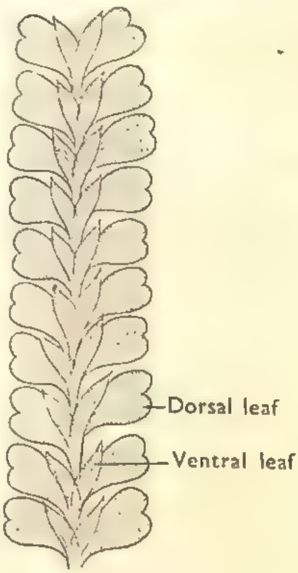


Fig. 248. *Lejeunea.* Plant body.

Reproduction

Lejeunea reproduces both by vegetative and sexual methods.

Vegetative reproduction may take place by three different ways: (*a*) by the death and decay of the older parts, thus separating the branches, which by subsequent growth, become independent plants; (*b*) by discoid **gemmae,** which are modified cells from the leaf margins; and (*c*) by **tubers,** which are modified underground branches.

Lejeunea is either monoecious or dioecious. The sex organs may be borne on the main axis or on short lateral branches.

The **antheridia** are usually borne on short lateral branches, but occasionally they are also found on the main stem. They are protected by bracts, known as **antheridial bracts** or **perichaetial bracts,** which are sub-equal. An antheridium develops from any superficial cell close to the apex. The mature antheridium is globose and has a jacket enclosing a number of antherozoid mother-cells, each of which gives rise to a biflagellate antherozoid. The cells of the jacket are strongly hygroscopic. The separation of jacket cells begin at the apex of an antheridium, due to an outward curvature immediately after they are wetted. The exposed mass of antherozoids begin to move freely in all directions.

A single **archegonium** develops from the apical cell of the female branch. The archegonia are protected by bracts (**perigonial bracts**) and bracteoles, which are different from the vegetative leaves. The archegonium consists of a *neck* and a *venter*. The neck consists of five vertical rows of neck cells and encloses 6-8 neck canal cells. The wall of the venter may be two-celled in thickness before fertilization.

At maturity there is gelatinization of the neck canal as well as the ventral canal cells. Thus, the archegonium opens at the tip through which antherozoids enter. Only one of them fertilizes the egg and an oospore is formed. *With fertilization and formation of oospore, the sporophytic or diploid generation begins.*

The sporophyte

The oospore by divisions forms the sporophyte. The mature sporophyte is differentiated into a **foot,** a **seta** and a **capsule.** There is no essential difference between a foot and a seta of the mature sporophyte of *Lejeunea* and those of the sporophytes of other Hepaticae. The capsule is pedicellate and globose. It may be hyaline or pale brown in colour. The capsule has jacket consisting of two layers of cells, the inner wall being often spongy. The differentiation of the elaters usually takes place long before the differentiation of the spore mother-cells. The elaters of *Lejeunea* have monospiral thickening, and each of them extends from top to bottom of the capsule with its upper end fixed to the capsule wall. The spore mother-cells, by reduction division, give rise to the tetrads of **spores.** *With reduction division and formation of spores, the gametophytic or haploid generation begins.*

The mature capsule typically opens by four valves. The opening extends up to 2/3 of the length of the capsule from the apex. The lower 1/3 of the capsule is solid. The elaters assist in spore dispersal.

The new gametophyte

The spore, on liberation, germinates immediately to give rise to a protonema-like structure. Finally from the protonemal stage, the mature gametophore is developed.

CLASS II. ANTHOCEROTAE

The Class Anthocerotae contains only *one* Order Anthocerotales.

Muller (1940) has divided Anthocerotales into *two* families (*a*) **Anthocerotaceae** and (*b*) **Notothylaceae.**

ANTHOCEROS

(Fam. ANTHOCEROTACEAE)

Most species of *Anthoceros*, commonly known as 'horned liverworts,' occur frequently along hillside roads and on very moist clay banks. They differ so greatly from the liverworts that the present-day workers separate them as a distinct Class co-ordinate with the Classes Hepaticae and Musci.

Anthoceros is a cosmopolitan genus with about 200 species and is found both in the hills as well as in the plains, in tropical and temperate regions. There are about 25 species occurring in India, of which the commonly growing ones are *A. himalayansis*, *A. erectus*, *A. crispulus*, etc.

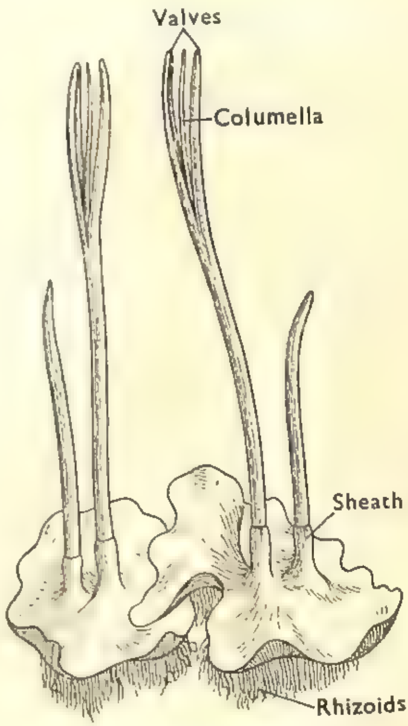


Fig. 249. *Anthoceros*. Thallus with sporophytes.

The gametophyte

The vegetative body of each plant is a small, dorsi-ventral and very simple, greasy dark-green gametophytic thallus, which is inconspicuously branched or somewhat lobed, and without any internal differentiation of tissues. There are numerous smooth-walled rhizoids on the under side of the thallus, the scales being entirely absent. On the ventral side of the thallus there are numerous large intercellular spaces, each of which opens externally by a narrow slit. These cavities are usually filled up with mucilage and often contain colonies of an endophytic

blue-green alga (e.g. *Nostoc*). Each cell of the thallus usually contains a single large chloroplast with a conspicuous pyrenoid, which is made up of numerous disc- or spindle-shaped bodies destined to be metamorphozed into small starch grains. Thus, it is evident that simplicity is the most prominent feature of the thallus in comparison with those of *Riccia* and *Marchantia*.

Reproduction

Anthoceros reproduces both by vegetative and sexual methods.

The vegetative reproduction is usually effected by progressive growth and death of the thallus. Under certain conditions of prolonged desiccation the gametophyte often produces **tubers**, formed due to marginal thickenings. Each tuber is externally protected by a cork layer and under favourable conditions gives rise to a new thallus.

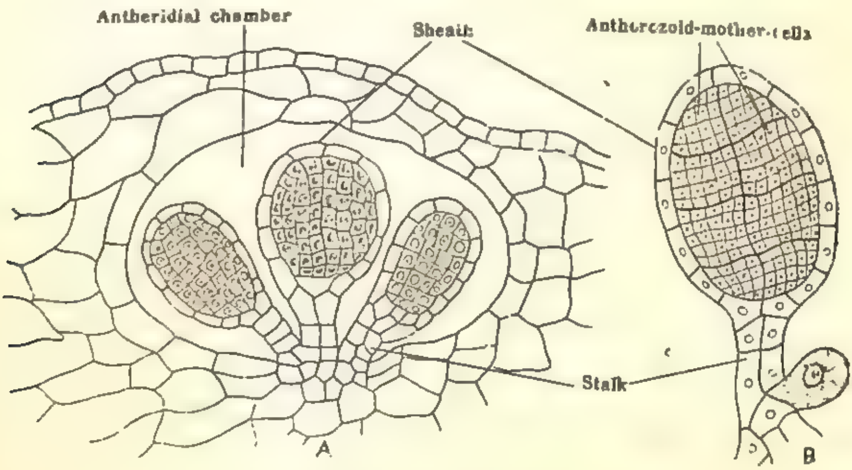


Fig. 250. *Anthoceros*.
A, Vertical section of a portion of thallus;
B, An antheridium (enlarged).

Anthoceros is mainly monoecious, though in some species the antheridia may attain maturity early (protandrous). It is a noteworthy feature that the sex organs are entirely embedded in the dorsal side of the thallus and not borne on special receptacles, as in *Marchantia*.

Antheridia develop in clusters within closed cavities (**antheridial chambers**) just beneath the upper surface of the thallus.

From the floor of each antheridial chamber two to four antheridia develop. The sterile layer over-roofing each antheridial chamber may be one or more (usually two) cells in thickness. Each antheridium develops a stalk of several cells in height. Numerous biflagellate antherozoids are produced from each antheridium. When the antheridia attain maturity the sterile cell layers, over-roofing each antheridial chamber, disintegrate and the antherozoids, are liberated.

Fig. 251. *Anthoceros.* Archegonia, young and mature.

Archegonia develop singly and are closely embedded in the thallus. The vegetative cells of the thallus are confluent with a part of the neck and venter of each archegonium, the extreme end of the neck being only protruding. When fully developed, there is a single axial row of cells in each archegonium, consisting of four to six neck canal cells, a ventral canal cell and an egg cell. At maturity, the neck canal cells and the ventral canal cell disorganize and fertilization of the egg is brought about by one of the antherozoids passing down the neck into the venter. After fertilization the fertilized egg secretes a wall around it and forms an oospore. *With fertilization and formation of oospore, the sporophytic or diploid generation begins.*

The sporophyte

The oospore, without any period of rest, divides and re-divides and forms a sporophyte. The sporophyte is gradually differentiated into a basal **foot,** and an upper slender cylindrical structure of more or less uniform thickness, the **capsule.** The zygote usually first divides longitudinally and then transversely. This is followed by another longitudinal division of the four daughter cells forming an eightcelled embryo, made up of two tiers of four cells each. The foot develops by division and re-division of the cells of the lower tier. When fully formed, it becomes a massive inverted cap-like structure, by means of which the sporophyte does not only remain

anchored to the gametophyte but also absorbs nourishment therefrom. The cells of the upper tier also by repeated divisions form the capsule, which, when very young, becomes differentiated into **amphithecium** and **endothecium.** When fully developed, the capsule stands erect on the thallus and attains a height of 2·5 cm. or more in some cases.

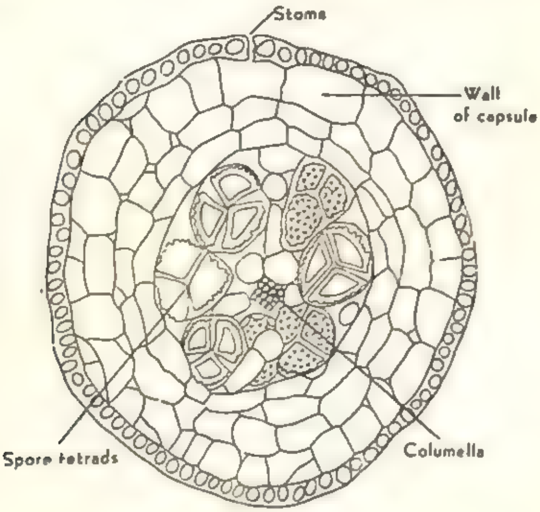


Fig. 252. *Anthoceros.* T.S. of capsule.

The structure of a mature sporophyte is very complex. At the centre there are some elongated cells forming a sterile tissue called **columella.** It appears 16-celled in rectangular arrangement in cross-section. The entire columella is derived from the endothecium. Surrounding and over-arching the top of the columella there is a cylindrical sheet of sporogenous tissue, the **archesporium.** The sporogenous tissue either remains one cell in thickness throughout its development or becomes two- to four-celled in thickness in some cases. Alternate groups of sporogenous cells develop into spores and elaters. Those sporogenous cells which behave as spore mother-cells undergo reduction division and from each a **spore tetrad** is formed. *With reduction division and formation of spores, the gametophytic or haploid generation begins.* The cells developing into elaters are joined with one another forming filaments of 3-4 cells each. Their walls are either smooth or thickened. The sporogenous tissue is again externally surrounded by a cylinder of sterile tissue possessing an epidermis. This jacket (of sterile tissue) and the entire archesporium are derived in most cases from the amphithecium. The outer cells of the jacket contain chloroplasts and the epidermis is provided with numerous stomata, each with a typical pair of guard cells. Thus, the sporophyte is able to carry on photosynthesis with the raw food materials absorbed

from the soil by the gametophyte and subsequently supplied to it as well as with carbon dioxide absorbed from the air. This ability

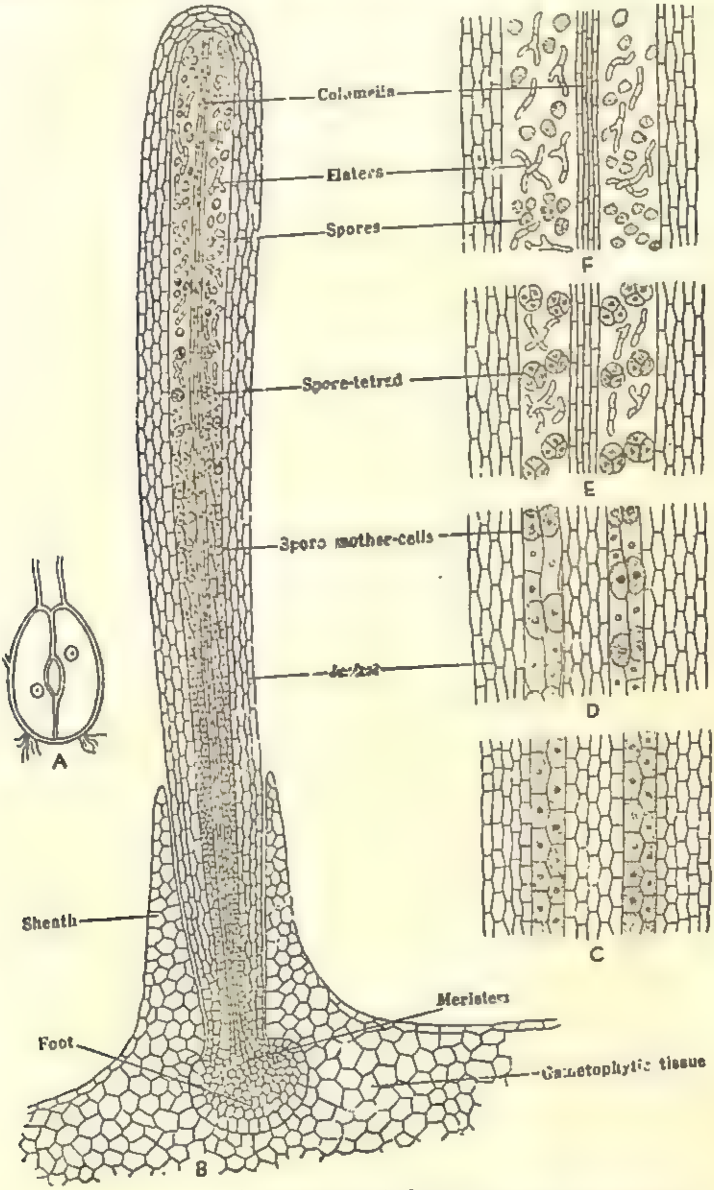


Fig. 253. *Anthoceros.*
A, A stoma; B, Longitudinal section of the sporogonium *in situ;* C—F, Longitudinal views of the same at different levels.

to synthesize carbohydrates is more highly developed than other

liverworts. The lower portion of the capsule is provided with a meristematic tissue, which continually adds new cells to the upper portion and, as a result, the capsule grows and produces spores over an extended period. The spore-production begins at the upper end of the capsule, and as the capsule grows, the spores are produced successively from lower layers. On maturity, the capsule dehisces at the apex into two valves and the split is continued downwards with gradual formation, maturation and liberation of spores. During the early stages of development of the sporophyte, the gametophytic tissue surrounding the archegonium also grows upwards, finally stops and forms a **sheath** surrounding the base of the developing capsule.

The new gametophyte

Each spore, under suitable conditions, germinates and forms a new gametophytic thallus.

NOTOTHYLAS

(Fam. NOTOTHYLACEAE)

Notothylas is generally found in damp, shady places, either on moist soil or on rocks. Sometimes, it also grows on the walls and floors of old buildings.

The genus is with about 11 species distributed both in the tropical and the temperate regions. There are 3 Indian species so far recorded, viz., *N. indica*, *N. levieri* and *N. chaudhuri*.

Fig. 254. *Notothylas*. Thallus with a few attached young sporophytes.

The gametophyte

The plant is thallose and prostrate with an orbicular or suborbicular form. It is thin and delicate, dichotomously branched, having a light green or yellowish colour. On the ventral surface it bears only smooth-walled rhizoids. The pegged rhizoids as well as the scales are entirely absent.

The thallus is marked for its external as well as internal sim-

plicity. It has but little internal differentiation of tissues. The middle region of the thallus may be 6-8 cells in thickness, whereas the margin is 1-3-celled thick. The epidermal cells are conspicuously smooth. Each epidermal cell contains a single large chloroplast with a pyrenoid. Some of the internal cells may contain mucilage and harbour *Nostoc* colonies within them, but in some species, such as *N. javanicus*, the thallus is solid and there is no mucilage-containing cell.

Reproduction

Notothylas reproduces both by vegetative and sexual methods.

Vegetative reproduction takes place by the progressive growth of the apical portion followed by death and decay of the older one behind the dichotomy of the thallus. As a result of this, when the point of dichotomy is reached the two lobes separate out, and thus, from the older plant two new individuals are produced.

The plant body is either monoecious or dioecious*. Some of the former are protandrous.

The **antheridia** grow close to the growing point of the thallus and they develop endogenously in groups of 3 or 4 (sometimes many) in chambers known as **antheridial chambers.** These chambers develop in the hypodermal region of the thallus. Each chamber is over-arched by a wall, two-celled in thickness. A mature antheridium is shortly stalked, somewhat oval and orange or red in colour. The antherozoids are typically biflagellate. They are liberated after the disintegration of the antheridial chambers.

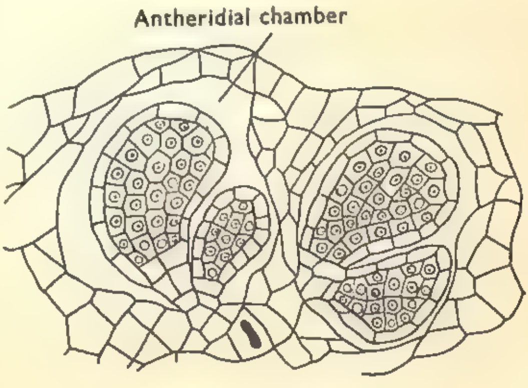


Fig. 255. *Notothylas.*
Section of thallus showing antheridia.

The **archegonia** develop singly close to the apex of the thallus. They are usually embedded in tissues of the gametophyte. A

* It is interesting to note that the Indian species are monoecious.

mature archegonium has 3-5 neck canal cells. The canal of the neck is wide and may be as wide as the venter. Within the venter a ventral canal cell and an egg are found. There are 4 **cover cells** at the apex of the archegonial neck. At maturity, the neck canal cells and the ventral canal cell disintegrate, thereby forming a passage for the entrance of the antherozoids.

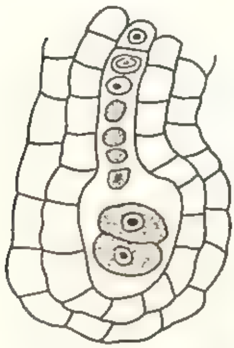


Fig. 256. *Notothylas.* An archegonium.

Fertilization takes place by the union of an antherozoid with an egg. The entry of the former in to the archegonium is facilitated by the presence of a thin film of water. The fertilized egg surrounds itself by a wall and forms the **oospore,** which almost completely fills the cavity of the venter. *With fertilization and formation of oospore, the sporophytic or diploid generation begins.*

The sporophyte

The oospore, by divisions and re-divisions, forms an *embryo* consisting of three tiers of cells. Of these three tiers, the uppermost one forms the *capsule* and the *seta*, while the two lower tiers produce the *foot*. From the very early stage the foot becomes bulbous. The seta remains rudimentary and remains ever meristematic.

The cells of the uppermost tier divide periclinally forming an outer amphithecium and an inner endothecium. The behaviours of the amphithecium and the endothecium are variable, depending upon the species. In *N. levieri*, where the columella is absent, the sporogenous tissue develops from the endothecium, and the jacket from the amphithecium. In *N. indica*, the sporogenous tissue is developed from the amphithecium. Campbell has shown that in some species of *Notothylas*, the sporogenous tissue develops partly from the amphithecium and partly from the endothecium.

The sporogonium, at maturity, becomes more or less cylindrical, sometimes tapering at both ends. They are borne horizontally along the margins of the thallus, either singly or in pairs. They are either partly or completely ensheathed by an **involucre** (developed from the parent thallus). The jacket of the capsule is more than one cell in thickness, and its outermost layer is heavily cutinized forming the epidermis. The cells of the epidermal layer contain chloroplast,

the stomata being absent entirely in this layer. The whole of the amphithecium or a part of it contributes to the formation of the jacket.

The sporogenous tissue differentiates into alternate transverse bands of sterile and fertile cells. The sterile cells ultimately form the **pseudo-elaters,** while the fertile cells form **spore tetrad** by reduction divisions. *With reduction division and formation of spores, the gametophytic or haploid generation begins.*

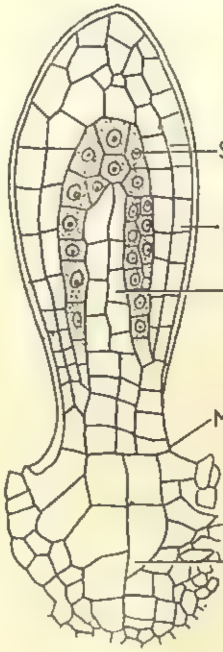


Fig. 257. *Notothylas.* V.S. of sporogonium.

Although the capsule is bivalved with well-developed sutures for dehiscence, in most cases the spores are liberated by the decay of the capsule wall. However, in some cases, dehiscence has been observed only along one of the sutures*. It is probable that the sterile cells and the columella, when present, may help in spore dispersal. The spores are tetrahedral and dark brown in colour.

The new gametophyte

A spore, on germination and subsequent development, gives rise to a new gametophyte.

CLASS III. MUSCI

The Class Musci has been divided by Smith (1955) into *three* subclasses: (*a*) **Sphagnobrya**†, (*b*) **Andraeobrya,** and (*c*) **Eubrya**‡.

* In rare cases dehiscence by two sutures also has been recorded.

† Sphagnales of Dixon.

‡ Bryales of Dixon.

SUBCLASS SPHAGNOBRYA

The protonema is broadly thallose and produces *only one gametophore*. The antheridia are borne in the axils of the leaves. The archegonia are formed acrogynously. The sporogenous tissue is derived from the amphithecium, whereas the columella from the endothecium. The capsule is elevated at maturity on a gametophytic tissue, the **pseudopodium.**

The subclass Sphagnobrya includes only *one* family, the **Sphagnaceae.**

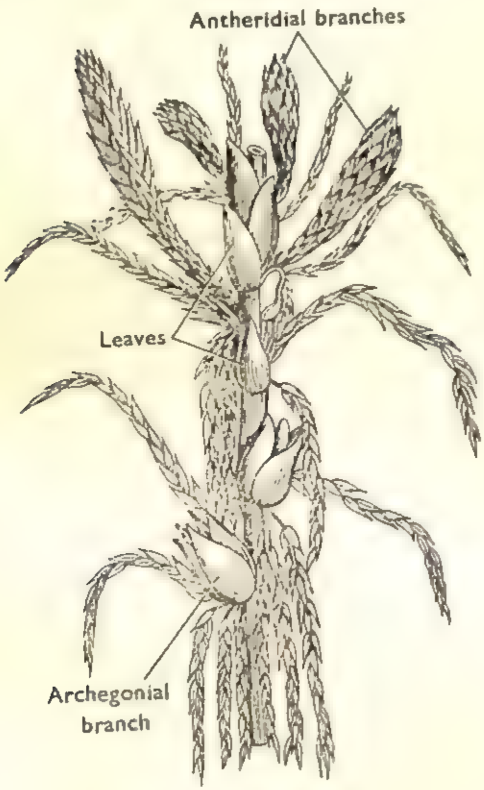


Fig. 258. *Sphagnum.*

SPHAGNUM

(Fam. SPHAGNACEAE)

Sphagnum, often known as 'bog- or peat-moss', is almost world-wide in distribution. It usually grows in swamps, ponds or other moist places on high altitudes, where the water is acidic and contains but little lime.

There are about 320 species of *Sphagnum.* The important Indian species are *S. ovatum*, *S. teres*, *S. robustum*, and *S. acutifolium.*

The plant is an upright leafy shoot, with radially arranged leaves, and is termed as the **gametophore.** The gametophore consists of a central stem-like axis with many branches densely covered with leaves. The branches are usually of two kinds: (1) **short and erect** ones crowded at the apex forming the 'head' of the plant, and (2) **long and drooping** branches, which help in fixation of the plant and absorption of nutrient solution in a wick-like fashion.

The leaves are small, and while young, are arranged in three vertical rows on the stem, but later on due to torsion, the three-ranked arrangement is lost. They are one-celled in thickness and may be composed of cells which are all similar, or of two types of cells, living and dead. The dead cells are large and hyaline with thick walls and pores. The living cells are long, narrow and contain chloroplasts comprising the photosynthetic tissue. The hyaline cells are capable of absorbing and retaining water.

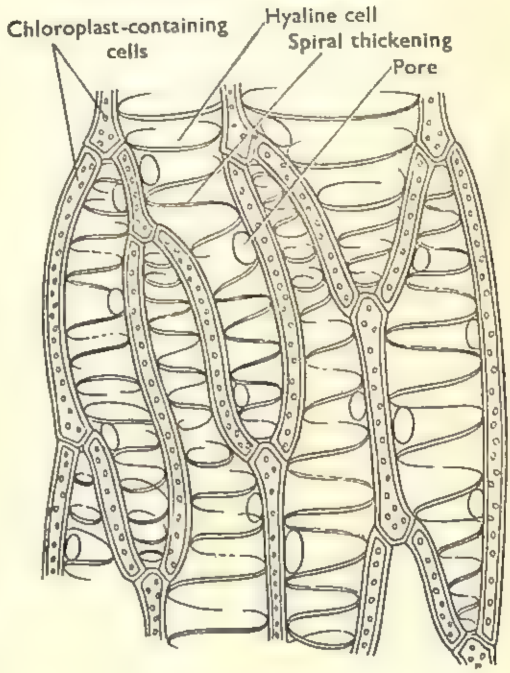


Fig. 259. *Sphagnum*. A portion of the leaf in surface view under microscope.

The stem is internally differentiated into a central cylinder and a cortex. The cortex is one-celled in thickness in the young stem and in lateral branches, but in mature main stem it is three or four cells in thickness. The cells of the central cylinder are elongated and may be homogeneous or heterogeneous. In the latter case, it contains dead and living cells, more or less similar to those of the leaves.

Reproduction

Sphagnum reproduces both by vegetative and sexual methods.

The only and efficient means of vegetative reproduction is by the lateral branches. The drooping lateral branches fix well within the substratum and after the death of the mother-plant become independent individuals.

The gametophyte may be monoecious or dioecious. The sex organs are borne on short, erect, lateral branches, and even in

the monoecious species the male and female sex organs are borne on separate branches.

The **antheridia** are developed in acropetal succession in the axils of the leaves of the antheridial branch. The antheridial branches are readily distinguished from the archegonial ones on account of pale colour of the former. A mature antheridium is globose or subglobose with a 2-celled, thick, long stalk. The jacket of the antheridium is one-layered. The antherozoids are liberated by the rupture of the antheridial jacket. These are biflagellate, spirally coiled and elongated structures.

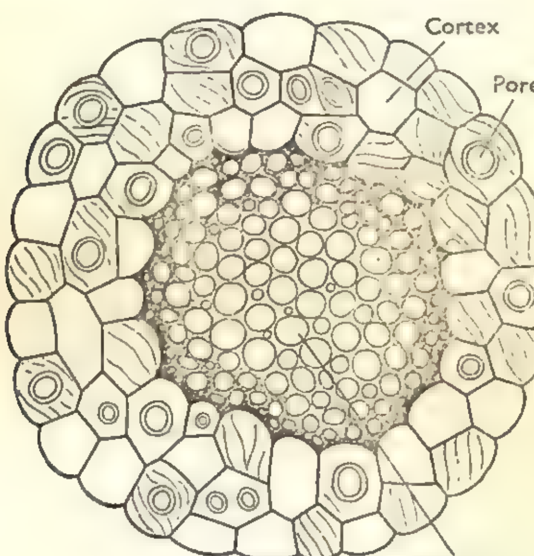


Fig. 260. *Sphagnum*.
T.S. of stem.

The **archegonia** are borne at the apices of the archegonial branches. Usually, there are three archegonia at the apex of each branch. A mature archegonium is relatively large with a stalk, a long neck and a massive venter. The neck contains several neck canal cells, whereas the venter contains one ventral canal cell and an egg.

The gametic union takes place during the spring. The liberated antherozoids swim towards the mature archegonium. Meanwhile,

the neck canal and ventral canal cells disintegrate forming a continuous passage. Finally, only one antherozoid swims inside

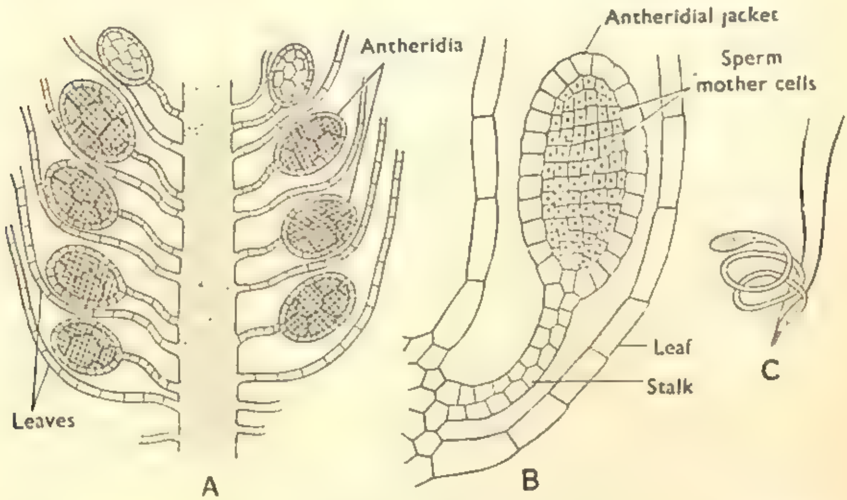


Fig. 261. *Sphagnum*.
A, Portion of L.S. of antheridial branch showing the leaves and the antheridia; B, An antheridium arising on a branch; C, An antherozoid.

the archegonium and fertilizes the egg. The fertilization of an ovum by the ventral canal nucleus has also been reported in a number of cases. The fertilized egg surrounds itself by a wall forming the **oospore.** *With fertilization and formation of oospore, the sporophytic or diploid generation begins.*

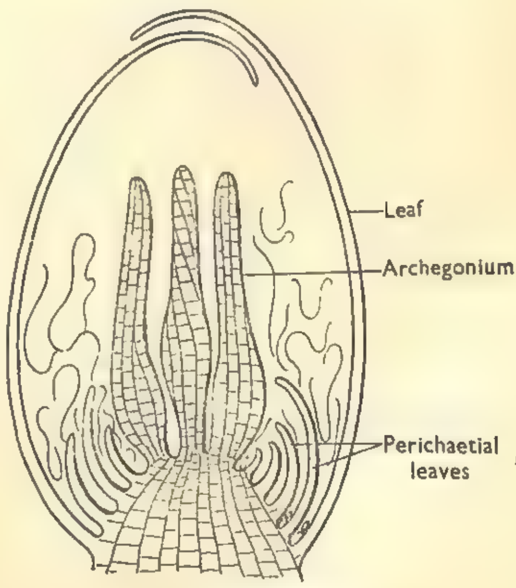


Fig. 262. *Sphagnum*.
A cluster of archegonia.

The sporophyte

The oospore by repeated transverse

divisions forms a filamentous embryo. The **capsule** develops from the upper portion of the filamentous embryo, the **seta** and **foot** from the sub-median region, and the **haustorium** from the lowermost portion. The haustorium helps in the absorption of nutrients from the gametophyte and is obliterated when the sporophyte matures. The foot and the seta are rudimentary.

Fig. 263. *Sphagnum.*
Gametophyte with attached sporophyte.

By successive cell divisions the capsular portion of the filamentous embryo forms a massive structure, within which periclinal divisions cut off an outer **amphithecium** and an inner **endothecium.** From the endothecium develops the **columella,** which occupies the central portion of mature capsule. The amphithecium, in its turn, by dividing periclinally gives rise to two regions, an outer and an inner. The sporogenous tissue, over-arching the columella, develops from the inner portion of the amphithecium, while the multi-layered jacket is developed from the outer region. The outermost layer of the jacket forms the epidermis bearing stomata. At the apical region of the mature capsule, the outermost layer forms the thick-walled **lid** or **operculum.** The spore mother-cells within the spore sac, by reduction divisions, forms the tetrads of **spores.** *With reduction division and formation of spores, the gametophytic or haploid generation begins.*

The mature capsule is dark brown or black in colour. It is protected by the **calyptra,** the remnant of the archegonial

venter. At the time of dehiscence, the mature capsule is elevated by a gametophytic tissue, known as **pseudopodium.** Due to the development of a differential air pressure inside the spore sac, the lid is explosively hurled off thereby liberating the spores.

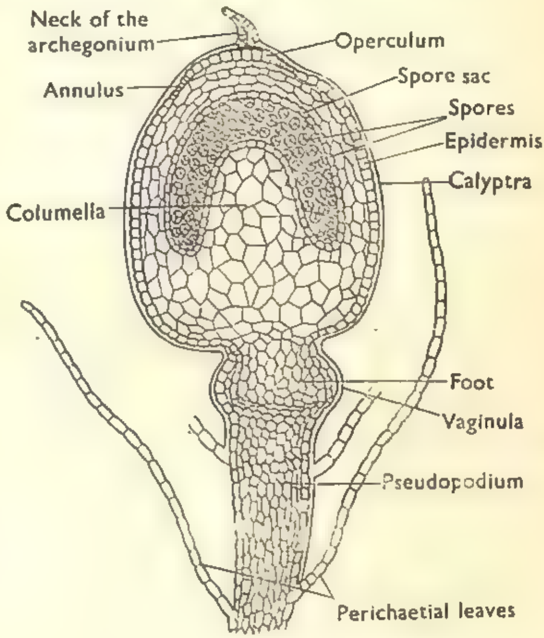


Fig. 264. *Sphagnum.* L.S. of capsule.

The new gametophyte

A spore, falling on a suitable substratum, germinates immediatey into a few-celled, thalloid **protonema.** The protonema, by subsequent cell divisions and growth, becomes a flat, green, prostrate and thalloid structure, which is irregularly lobed and is attached to the substratum by means of multicellular rhizoids. On this protonema, there develops a single lateral bud, which ultimately forms a new gametophore.

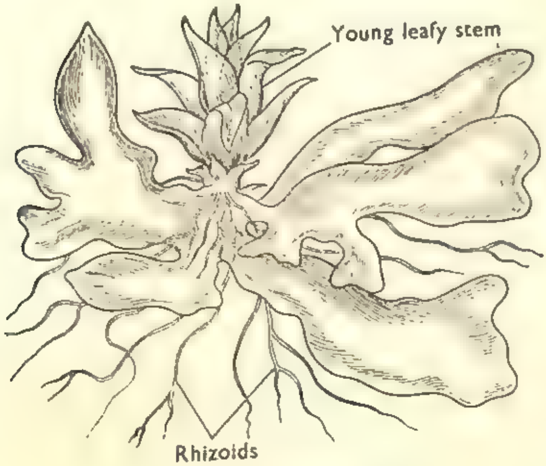


Fig. 265. *Sphagnum.* Development of a new gametophyte.

SUBCLASS EUBRYA

The protonema is filamentous and *develops more than one gametophores* with prominent midribs. Both the sporogenous tissue as well as the columella are developed from the endothecium, the latter penetrating the former. The capsule dehisces irregularly, or opening by a lid. The mature capsule is elevated by the seta at maturity.

Dixon (1932) has divided the true mosses (Bryales) into 17 Orders: (*a*) **Tetraphidales,** (*b*) **Calomniales,** (*c*) **Schistostegales,** (*d*) **Buxbauminales,** (*e*) **Polytrichales,** (*f*) **Fissidentales,** (*g*) **Grimmiales,** (*h*) **Dicranales,** (*i*) **Syrrhopodentals,** (*j*) **Pottiales,** (*k*) **Encalyptales,** (*l*) **Orthotricales,** (*m*) **Funariales,** (*n*) **Eubryales,** (*o*) **Isobryales,** (*p*) **Hookeriales,** and (*q*) **Hypnobryales.**

ORDER **POLYTRICHALES**

The gametophyte is mostly a tall perennial plant. The leaves are narrow and are usually provided with longitudinal lamellate structures, either on the back or on the ventral surface of the nerve. The cells of the leaves are essentially parenchymatous. The capsule is horizontal to erect and is provided with a rostrate lid. The calyptra is smooth, spinulose or hairy. There are 32 or 64 teeth in the peristome.

Two families are included by Dixon within the Order: (*a*) **Dawsoniaceae,** and (*b*) **Polytrichaceae.**

POLYTRICHUM (=*POGONATUM*)

(Fam. POLYTRICHACEAE)

Polytrichum, often known as 'squirrel tail moss' or 'hair moss', is one of the common mosses of Indian Archipelago and Australia, which grows in the rainy season on damp ground, near the base of tree trunks and side walls of cities forming dense tufts and patches.

There are about 92 species of *Polytrichum,* of which 4 are commonly found in India, viz.; *P. commune, P. juniperinum, P. densifolium,* and *P. xanthopilum.*

The gametophyte

The gametophyte is differentiated into two portions: a prostrate and much-branched alga-like filamentous portion, the **protonema,** and an upright persistent leafy shoot, the **gametophore.** The filamentous protonema is transitory and shows two kinds of branches: the ordinary green ones with straight transverse septa, and the brown-walled ones with strongly oblique septa, the **rhizoids.** If abundant moisture is present, this protonema grows to a considerable extent and sooner or later there arise, from its distal end of the cells, lateral pear-shaped multicellular cell-masses (**buds**), from each of which a leafy gametophore is produced.

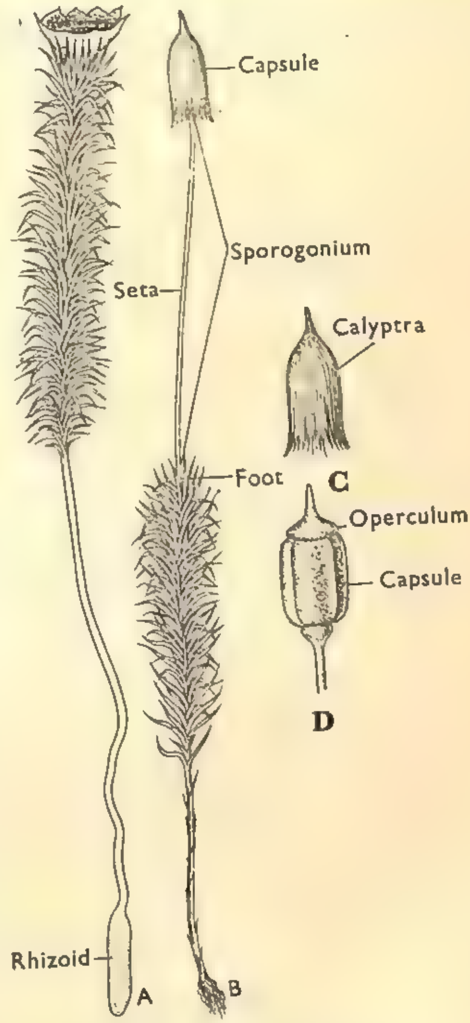


Fig. 266. *Polytrichum commune.*
A, A male plant; B, A female plant with sporogonium; C, Calyptra; D, Capsule with calyptra removed.

The gametophore, which is independent at maturity, often reaches a height of 20-40 cm. and is always differentiated into an angular stem and closely-set, thick, rigid, spirally arranged leaves (with angular divergence 5/13, 14/34, etc.). The leaves are small, very numerous, lanceolate to linear in outline, and with a very broad and strong midrib, projecting beyond the apex of the lamina. The lamina which develops only at the extreme margin of the midrib is usually more or less incurved. A leaf, when viewed

with a pocket lens, shows that, as if, there are several narrow mid-ribs. But when sectioned and examined under microscope, these are found to be thin vertical plates of chloroplast-containing cells along the middle region of the leaf and are the incurved margins of the lamina which protect them in dry weather. At the base of the shoot numerous rhizoids develop and these often become closely twisted together to form cable-like strands.

A cross section of a mature aerial stem shows three distinct regions: a firm epidermis, a comparatively thick cortex and a central cylinder. A few outer layers of cells of the cortex are thick-walled and dark-coloured like the epidermis, but more compact than the inner colourless parenchymatous ground tissue. The central cylinder is composed of two tissue elements; thick-walled, dark-coloured cells with living protoplasts (**stereids**) especially abundant towards the centre, and larger, thin-walled, empty cells (**hydroids**), almost destitute of protoplasm and resembling vessels of true vascular plants. Starch has been noted in the outer cells of the cortical region. This central cylinder is separated from the cortex by an incomplete pericycle-like sheath of thin-walled living cells. 'Leaf traces' are also present in the cortex and these are structurally similar to the central cylinder.

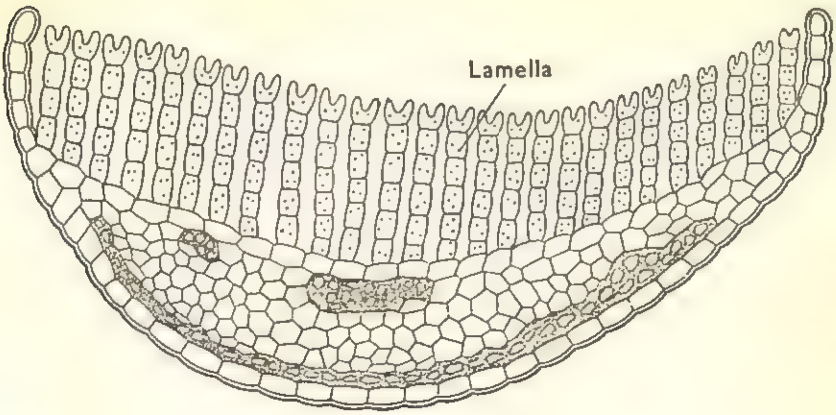


Fig. 267. *Polytrichum commune.*
Transverse section of leaf (in part).

Reproduction

Polytrichum reproduces both by vegetative and sexual methods.

The protonema multiplies by the separation of its branches, which may grow into few protonemata. Often colourless **separation cells** appear and break the protonema into several filaments. **Gemmae** are often developed from the terminal cells of the protonemal branches. These gemmae may directly give rise to new protonemata. Vegetative reproduction may also be carried on by the development of secondary protonemata, which are formed from any

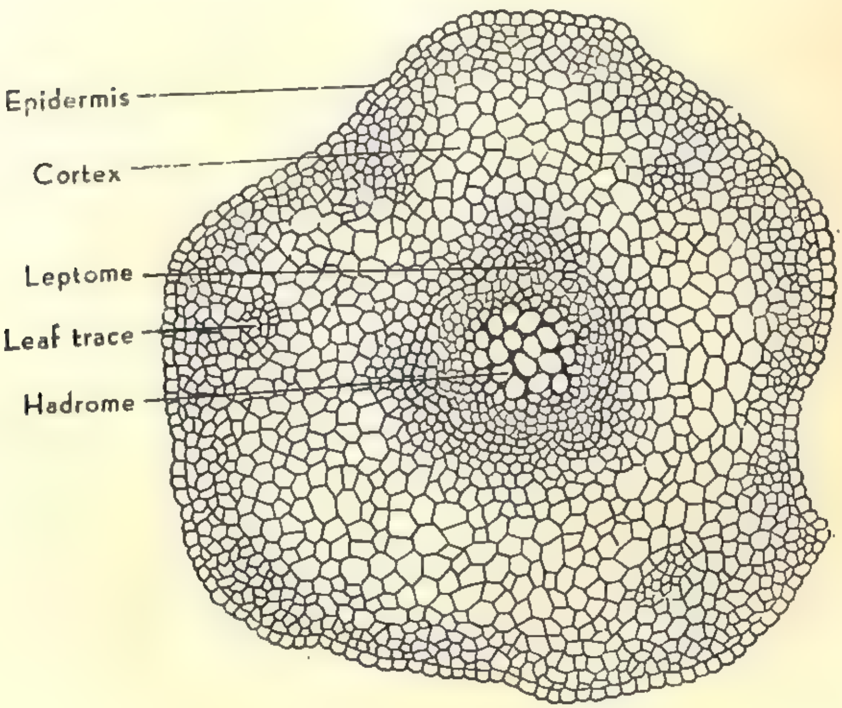


Fig. 268. *Polytrichum*.
Transverse section of the stem.

part of the plant, e.g., rhizoids, leaves or stem. Sometimes protonemata are produced from the sporogonium without the formation of spores. This is a case of **apospory.**

Polytrichum is usually dioecious and the sex organs, antheridia and archegonia, are borne separately at the apices of male and female gametophores respectively, forming the so-called 'inflorescences'.

Each inflorescence consists of a group of sex organs which are surrounded by specialized leaves, **perichaetial leaves,** quite different in form and colour from those on the stem.

The conspicuous male inflorescence consists of a group of antheridia intermingled with peculiar sterile green hairs (**paraphyses**) and is surrounded by broad, reddish and membraneous perichaetial

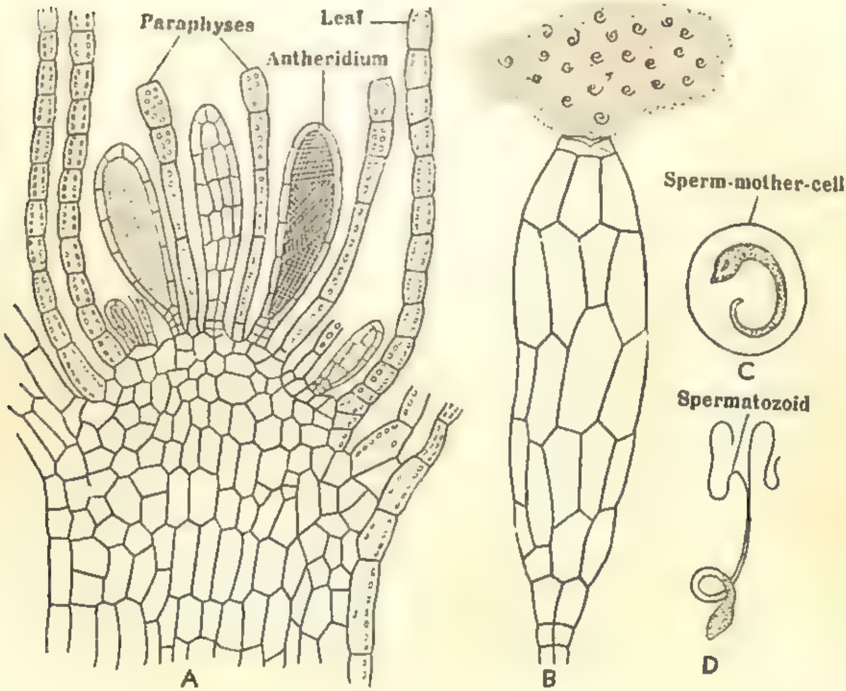


Fig. 269. *Polytrichum.*
A, Longitudinal section through the apex of a male plant showing antheridia and paraphyses; B, A mature antheridium discharging spermatozoids; C, Spermatozoid mother-cell; D, A spermatozoid.

leaves. The growth of the apical region of the stem is, however, not stopped by the formation of antheridia, and its further growth may be resumed when the formation of antheridia is totally stopped. This inflorescence is regarded as a compound structure, since groups of antheridia develop at the base of each leaf of the

inflorescence and it is quite probable that each group represents a condensed branch.

Each **antheridium** is a shortly stalked, club-shaped body containing within it many mother-cells of the spermatozoids (**androcyte cells**) and within each of which a biflagellate spermatozoid is developed. When ripe, the antheridium has a yellowish or orange colour and opens at the top (multicellular **opercular cap**), the whole mass of spermatozoid mother-cells escape and finally from these mother-cells the spermatozoids are discharged in the surrounding film of water, which wets the surface of moss bed.

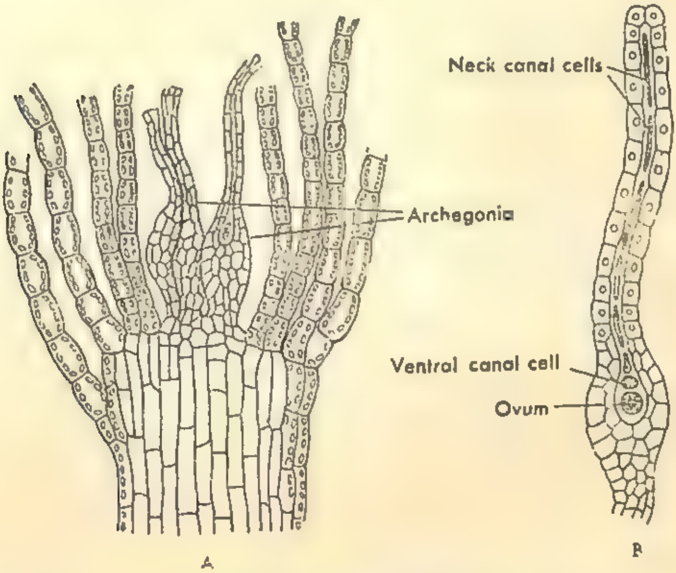


Fig. 270. *Polytrichum*.
A, Longitudinal section through the apex of a female plant showing archegonia; B, A mature archegonium.

The **archegonia,** borne on a separate plant, are also in a cluster at the apex of the gametophore and the perichaetial leaves usually remain folded over them. Each archegonium is a flask-shaped body with a very short stalk and consists of two parts: a basal swollen portion, the **venter,** and a comparatively long upper portion, the **neck.** The venter contains a ventral canal cell and a

female cell, the oosphere, or ovum, or egg. In this case there is a variable number of *neck cells.*

When an archegonium matures, a passage is established due to the disorganization of the canal cells. This passage becomes filled with a mucilagenous substance containing canesugar. Fertilization takes place in water. Biflagellate spermatozoids, swimming by means of flagella, come in the neighbourhood of archegonium; these being attracted by the canesugar penetrate the neck, but only one of them fuses with the ovum. The fertilized ovum then surrounds itself with a cell wall and becomes an **oospore.** The ova of several archegonia may be fertilized forming oospores, but the one which is formed first begins to grow on getting food while the rest dry up, so that only one sporophyte develops over a leafy gametophore. *With fertilization and formation of oospore, the sporophytic or diploid generation begins.*

The sporophyte

The oospore gradually passes into an embryo, which ultimately gives rise to the **sporogonium,** the sporophytic generation of the moss plant. Due to the rapid growth of the sporogonium, the upper portion of the archegonium-neck becomes torn off, so that it is carried off in the form of a cap, ultimately forming a very large hood-shaped **calyptra** covered with a dense growth of hairs.

The sporogonium consists of three parts: (*a*) a sac-like upper part, the **capsule,** (*b*) a slender stalk called **seta,** and (*c*) a small **foot** by means of which it is attached to the gametophyte. The capsule is at first green in colour owing to the possession of chloroplasts and in its lower portion it bears a few stomata. Within the capsule the spore-bearing tissue, the sporogenous tissue, develops from which ultimately **spores** are formed (four spores from each spore mother-cell due to reduction division). A large part of the central tissue of the capsule remains sterile forming the so-called **columella** and the conical upper part, the **operculum,** which becomes detached from the lower part as lid in order to allow these spores to escape; the operculum is prolonged into a beak-like **rostrum.** Just beneath the operculum there is a complicated structure known as **peristome** consisting of 32 or 64 'teeth' in a circle around the mouth of the spore-cavity of the capsule. These are nothing but bundles of thickened fibrous cells, regularly

arranged in crescent form resembling the spokes in a wheel. These teeth help to scatter the spores. The tip of the columella is expanded into the **epiphragm,** filling the space inside the peristome ring. There are two large intercellular spaces surrounding the sporogenous tissue, one on its outer side and the other between it and the columella, and are traversed by narrow filamentous

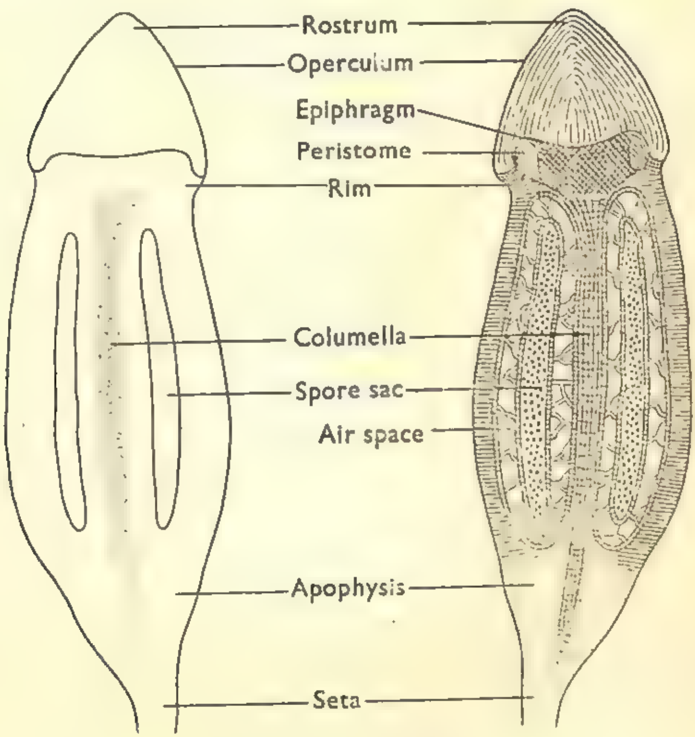


Fig. 271. *Polytrichum.*
Median longitudinal section of a capsule.
(Diagrammatic).

strands of cells containing chloroplasts. At maturity the capsule finally becomes horizontal and dorsiventral. *With reduction division and formation of spores, the gametophytic or haploid generation begins.*

The new gametophyte

When the spores mature they are shed by means of peristome. These may rest for some time but when they germinate, under

favourable conditions, directly give rise to **protonemata.** Lateral buds arise from the protonema and each produces a new moss plant.

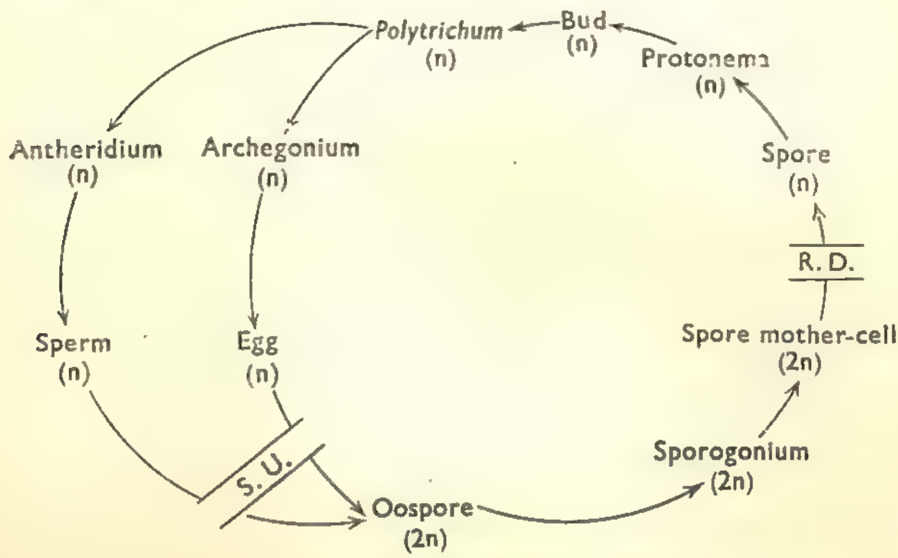


Fig. 272. Life cycle of *Polytrichum.*

ORDER **POTTIALES**

The plants are mostly small and the leaves are variable. The mesophyll cells are isodiametric, usually opaque and small. The capsule is borne on a long and thin seta. It is cylindrical and erect. The calyptra is narrow. There are 16 teeth in the peristome.

The Order includes only *one* family: **Pottiaceae.**

BARBULA

(Fam. POTTIACEAE)

Barbula is a common moss that grows profusely and gregariously forming dense bright yellowish-green masses in damp places and on brick walls during the rainy season, and usually in association with other mosses. So far four species of *Barbula* have been recorded in India, viz., *B. indica*, *B. comosa*, *B. orientalis*, and *B. gangetica*.

The gametophyte

The vegetative body of the gametophyte consists of two portions, *viz.*, a prostrate, green, filamentous portion, called the **protonema** and a differentiated vegetative shoot, the **gametophore.**

The protonema is derived from a spore as a result of germination. When fully developed, it is a much-branched filamentous structure, which is differentiated into an extensive green portion, the **chloronema,** and a pale green slender branched portion that gives rise to rhizoids. Each portion consists of several cells, which are delimited from one another usually by walls. The chloronema is positively phototropic and remains on the surface of the substratum, while the rhizoidal system is negatively phototropic and grows vertically down into the substratum.

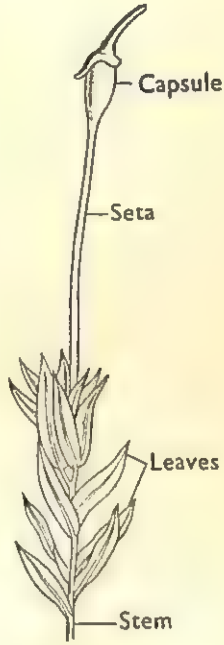


Fig. 273. *Barbula.* A gametophore with an attached sporophyte.

The gametophore takes its origin from the bud developed on the protonema. The bud is a two- or three-celled structure, which enlarges and becomes somewhat pear-shaped. By further divisions an apical cell is ultimately differentiated, and from this cell the gametophore develops. The gametophore, when fully developed, is erect and usually consists of a simple axis (stem) bearing numerous spirally-arranged minute leaves and with smooth-walled rhizoids at the base. The rhizoids have oblique walls and are brown in colour in older portion. The leaves are lanceolate with obtuse apex, margin recurved and minutely sinuate, and with a strong midrib projecting beyond the apex of the blade. In younger portion of the gametophores, the leaves show tristichous arrangement, but in the older portion this arrangement is lost.

A cross section of the stem shows two distinct portions, namely a central cylinder made up of thin-walled, narrow, polygonal cells (elongated in longitudinal section) and an outer cortical region with much larger cells with thicker and yellowish-brown cell walls at

maturity. When young, the cortical cells contain chloroplasts. An epidermal layer is, however, not clearly differentiated.

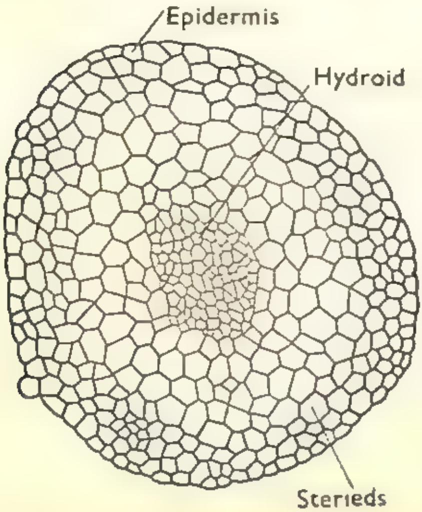


Fig. 274. *Barbula*.
T.S. of stem.

Reproduction

Barbula reproduces both by vegetative and sexual methods.

Vegetative propagation in *Barbula* takes place in three ways :

(*a*) by the formation of brute bodies, which arise as axillary multicellular, branched, filamentous bodies from a single or a group of superficial cells of the axis. The apical cells of these branches along with a few other cells, increase in volume, turn dark green and become filled with dense cytoplasmic matter, and by a series of irregular divisions develop thick-walled, yellowish brown multicellular bodies, known as **brute bodies (propagula)**.

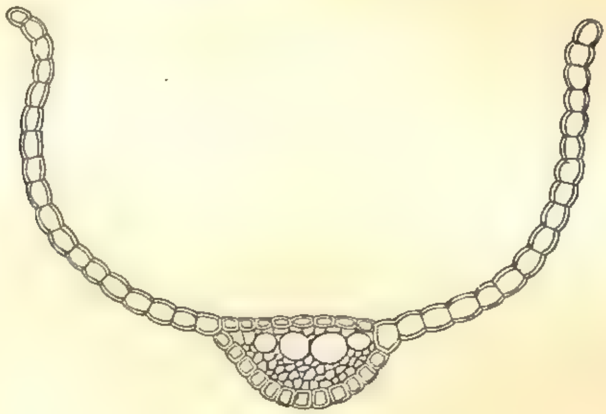


Fig. 275. *Barbula*.
T.S. of leaf.

The brute bodies, on germination, produce protonema and rhizoids;

(*b*) by the production of protonema from any part of the mature gametophore;

(*c*) by the elongation and subsequent development of a few leaves from the apex of the parent gametophore, after a long period of drought; the portion finally gets itself detached from the parent plant and develops into a new gametophore.

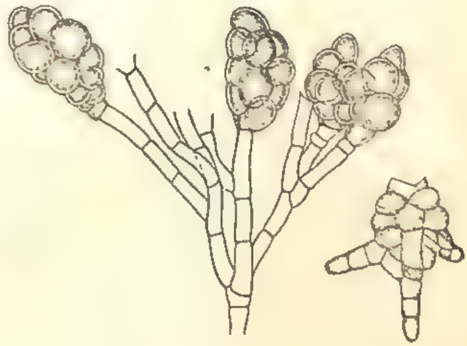


Fig. 276. *Barbula*.
A, Brute bodies; B, Germination of the same.

Barbula is strictly dioecious, the male and female plants occur in separate or intermingled masses. The sex organs usually occur at the apex of the main axis of the gametophore, but they also develop on the apices of the branches when the gametophore is branched. Both types of sex organs are associated with long, filamentous, multicellular **paraphyses** with pointed ends. They may remain intermingled with antheridia in male plants, but surround the central group of archegonia in female plants.

A mature **antheridium** is a club-shaped structure and shortly stalked, and contains within it numerous mother-cells of the spermatozoids (**androcyte cells**), and each of which is metamorphozed into a long, slender, coiled spermatozoid with two flagella attached to one end. The spermatozoid mother-cells lie entangled in a mucilagenous mass within the mature antheridium and are ultimately discharged through the apex by the rupture of its wall.

An **archegonium** is a flask-shaped body with a very short stalk and consists of two portions, namely, a basal portion called the *venter* and a comparatively long upper portion, the *neck*. The venter contains ventral canal cells and an egg or ovum. Within the neck there is a central row of 12 neck canal cells. At maturity, the apex of the neck splits open and all the neck canal cells and ventral canal cell disorganize to form a continuous passage.

In presence of water the spermatozoids swim out of an antheridium, enter the neck of the archegonium, reach the egg and only one fuses with it. After fusion the egg secretes a wall around it and

The stem is differentiated internally into epidermis, cortex and central cylinder. The epidermis is one-layered, being composed of thick-walled parenchymatous cells. The cortex is multi-layered, and the cells contain chloroplasts, and in the outer region their walls are thickened. The central strand is composed of thin-walled, elongated cells forming a conducting tissue.

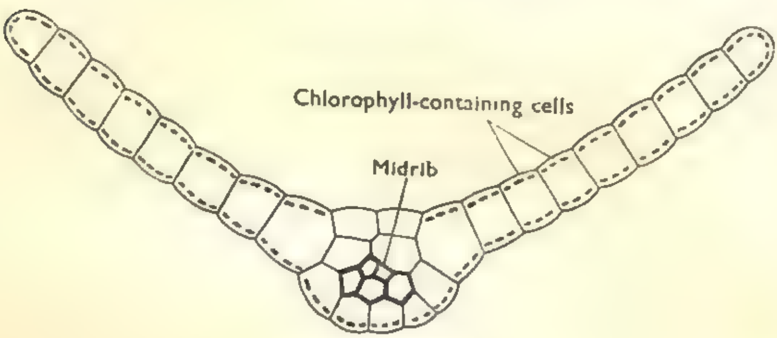


Fig. 282. *Funaria*.
T.S. of leaf.

The midrib of the leaf is multi-layered, thick and contains a strand of thin-walled conducting cells similar to those of the stem. The remaining portion of the leaves are one-celled in thickness, each of which contains chloroplasts. These cells constitute the photosynthetic tissue.

Reproduction

Funaria reproduces both by vegetative and sexual methods.

Vegetative reproduction takes place in the same way as in *Polytrichum*.

Funaria is monoecious, but the sex organs are borne on separate branches. The antheridia are borne at the apex of the main stem, while the archegonia at the apices of the lateral branches, which arise from the base of the main axis and soon overtop the latter.

The **antheridia** are produced in clusters in association with bract-like leaves, which form a rosette at the apex of the antheridial branch and form the **perichaetium.** A mature antheridium is an elongated, club-shaped structure borne in a short, stout, multicellular stalk. The antheridia are inter-mingled with a large number of multicellular hairs, known as **paraphyses.** The jacket of

each antheridium is one-layered and encloses numerous biflagellate antherozoids or spermatozoids. The mature antheridium, when comes in contact with water, bursts at the apical region, thereby liberating the antherozoids.

The **archegonia** are also produced in clusters, but here the leaves enclosing the archegonia are similar to ordinary foliage leaves. A mature archegonium is a much-elongated structure, borne on a short, multicellular stalk. It has a swollen venter and a long neck. The wall of the venter is two-celled thick. The neck is composed of 6 vertical rows of cells, which surround a central canal. There are several *neck canal cells* in the neck, and a single *ventral cell* and an *egg* in the venter.

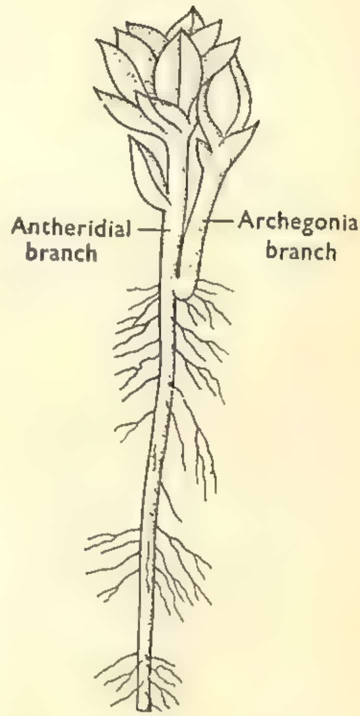


Fig. 283. *Funaria.* A portion of the gametophore bearing several branches.

Fertilization takes place in presence of water. The antherozoids reach the archegonium by swimming in water. Meanwhile, a continuous passage is formed within the archegonium by the dissolution of the neck canal cells and the ventral canal cell. The antherozoids are supposed to be attracted by a sugary fluid secreted from the archegonium. A single antherozoid enters the archegonium and ultimately fertilizes the egg. The fertilized egg soon surrounds itself by a wall forming the **oospore.** *With fertilization and formations of oospore, the sporophytic or diploid generation begins.*

The sporophyte

The oospore divides transversely into a lower **hypobasal cell** and an upper **epibasal cell.** The **capsule** develops from the epibasal cell, while the **foot** and **seta** from the hypobasal one. The cells of the epibasal region divide periclinally forming an outer

Evolution of sporophyte among Bryophyta

It was first formulated by Bower (1890) that in the archegoniates, the spore-producing generation, the sporophyte, is an entirely new phase, derived from the progressive elaboration of zygote, and is intercalated within the gametophytic generation as a result of adaptation to land habit. This hypothesis was later supported by Chamberlain (1935), Smith (1938) and others. Further elaboration resulted in the sterilization of potentially sporogenous tissue. The most primitive sporophyte in the hepatics occurs in the genus *Riccia*. Such a sporophyte, according to some authors, is nearest to the hypothetical ancestors, represents the actual ancestors of the more highly evolved plants. Here, the entire structure is involved in the production of the spores with the exception of one layer of sporogenous wall. Frequent abortion of spore mother-cells possibly represents the beginning of elaters. From this primitive type, complex sporophytes evolved in different directions, all having a foot, a seta and a capsule arising from the zygote. Each of these organs shows diversity in structure and form. In *Sphaerocarpus*, a step advanced than *Riccia*, a sterile foot and a seta, each of a few cells are present; the one-layered jacket of the capsule, apart from the spores, contains sterile cells homologous with elaters. These sterile cells, however, do not show the characteristic thickening. Another step in evolution is the sporophyte of *Targionia* with a broad foot and a narrow seta, and which contains spores intermingled with elaters. The jacket of the capsule consists of a layer of cells, except at the apex.

The highest evolved type among the Marchantiales, is found in *Marchantia*, where the upper half of the embryo gives rise to capsule and part of the seta, while the other half, develops into the remaining part of the seta and the inverted hood-like foot. The jacket of the ovoid capsule is very similar to that of *Targionia*, in having a layer of cells except at the tip. It splits up, at maturity, into a number of segments. About half of the internal tissues develop into spirally thickened elaters, while the rest into spores.

A still more advanced type is to be seen in the leafy liverworts, where there is a well-developed foot, a long seta and a capsule with a jacket more than one-celled thick. The dependent sporophyte can partly manufacture its own food due to presence of chlorophyll, stomata and air spaces within the jacket layer. Dehiscence is regu-

larly into 4 valves. Further sterilization is noted in the development of an elaterophore, arising from the base of the capsule in *Pellia* and from the apex in *Riccardia.*

The most complex sporophyte and culmination of this series is noted in the Anthocerotales. In *Anthoceros*, the foot is well developed, and the capsule is cylindrical in form. The latter has a jacket layer, 4-6 cells in thickness; stomata and chlorophyllous tissue help in food manufacture. Under exceptional cases; the sporophyte of *Anthoceros fusiformis* can become an independent plant, characteristic of higher plants. The layer of sporogenous tissue within the capsule is very narrow and overarch the centrally situated columella, which is interpreted as the forerunner of vascular tissue. The jacket may split up into two valves. A nutritional independence and the provision for continued growth of the sporophyte due to the presence of meristimatic tissue at the base of the capsule, have led many a pteridologists to believe the anthocerotean type of sporophyte as the ancestors of the Pteridophytes.

The often partially independent sporophytes of mosses though showing a greater amount of sterilization of potentially sporogenous tissue, and well-developed mechanism for spore dispersal, are considered due to their determinate growth, to represent a completely different, and blind evolutionary line. In *Sphagnum*, similar to that of *Anthoceros* the foot is bulbous and the seta is rudimentary. The Anthoceros-like feature is further emphasized by the production of columella from the endothecium, and the jacket layer as well as the sporogenous tissue from the amphithecium. The completely dependent sporophyte dehisces by an operculum and is elevated at maturity by pseudopodium, which is composed of the gametophytic tissue.

Of the Musci, *Sphagnum* is generally recognized as the most primitive, due to the significant points of structure between *Sphagnum* and *Anthoceros*, indicating a possible remote relationship. The sporophyte is the most characteristic and complicated structure in the true mosses, like *Funaria*, *Barbula*, etc., in having a foot, a long seta, the apophysis, the several-layered wall of the capsule, the columella, the wall of the spore sac, the peristome and the operculum. In these cases the columella and the sporogenous tissue are derived from the endothecium, while the amphithecium develops into jacket. Teeth of the peristome exhibit pronounced hygroscopic movements. In a moist weather the teeth bend down over

the spore sac to stop spore liberation, while in a dry weather the peristome teeth bend outward to facilitate the shifting out of spores from the spore sac.

In about half a dozen genera of the mosses, the capsule does not open by a definite operculum and no peristome is present. The capsule opens irregularly; and these genera were often grouped together as *Cleistocarpi*, contrasted with the remaining ones, known as *Stegocarpi*, which have a definite peristome and operculum. The ontogeny of cleistocarpous sporophytes is essentially the same as in stegocarpous mosses, and it is generally held that cleistocarpy has appeared in unrelated lines among the true mosses.

Economic importance of Bryophytes

The economic importance of the bryophytes is not obviously apparent, but they may be beneficial indirectly. The bryophytes are, practically speaking, the first colonizers on bare and exposed grounds. By their actions, which are partly mechanical and partly chemical, they can convert the top surface of rocks, lava or similar other substrata into soil. Then, when some of them die this soil becomes enriched with the organic matter. Subsequently, the pteridophytes and the seed-bearing plants appear in succession and finally a bare rocky surface is converted into a green forest. Further, on account of their extremely high capacity for absorbing and retaining water, they help in preventing soil erosion, and even may control flood to some extent.

The bryophytes are very important economically as they form the peat, which can be used as a fuel in place of coal. The peat is produced as a result of accumulation of mosses, particularly *Sphagnum*, in huge numbers in swamps and bogs; these mosses undergo slow decomposition and become compacted and carbonized. The 'peat moss' prepared from *Sphagnum* is used by the poultry people as bedding for the livestock as well as by the gardeners to increase the water-retaining capacity of the soil and for keeping it porous.

Shagnum and other mosses, growing on the banks of ponds, jheels and lakes, form the quaking bogs, whose water appears to possess antiseptic and preserving properties. The larger mosses are sometimes used for packing delicate and fragile materials. Previously they were employed for stuffing furniture. The horticulturists and florists utilize *Sphagnum* for packing seedlings, cut

flowers and other nursery stocks. It is also used as a substratum for germinating seeds. On account of the extremely efficient absorptive and antiseptic properties *Sphagnum* was used extensively for dressing wounds during the Russo-Japanese war as well as in World War I.

CHAPTER V

PTERIDOPHYTA

The pteridophytes include plants like ferns, horsetails, club-mosses and their allies, and are widely distributed in the temperate and tropical regions. They are frequently found in most terrestrial habitats but many grow as floating aquatics or may even be epiphytes on tree trunks. They have a well-defined alternation of generations in their life cycles and the *sporophyte is always an independent plant* and free from the gametophyte at maturity. The *gametophyte*, on the other hand, is either *wholly independent of the sporophyte or may be partially or wholly dependent on it* for nutrition and is always smaller than the sporophyte. The plant body is usually well differentiated into stem, root and leaves, and with an internal conducting system consisting of xylem and phloem. The asexual generation or the sporophyte may be **homosporous** (with spores of one kind) or **heterosporous** (with spores of two kinds, viz., small or **microspores** and large or **megaspores**). The Pteridophytes differ from the Bryophytes in having an independent sporophyte with well-differentiated vascular structures. They also differ from the seed-bearing plants (Spermatophytes) in the liberation of the female gametophyte from the sporangium. The method of sexual reproduction resembles that of the Bryophytes.

The principal feature of the stem is its conducting system. This is known as **stele;** it is worth noting the different kinds of steles with their names, as all pteridophytes and all plants above them have steles of one kind or another. The principal tissues of the steles are *xylem* and *phloem*. Outside the stele there is always a cortex limited externally by an epidermis; and inside it there is often a pith. The names of different kinds of steles depend upon the relative positions of these parts. It may be a **protostele,** where the xylem represents a central solid cylinder surrounded by phloem (e.g., *Lycopodium*, *Gleichenia*—a fern, etc.). In an **amphiphloic siphonostele** the xylem is in the form of a hollow cylinder with phloem on both sides, external and internal, and there is always a central pith (e.g., *Adiantum*—maiden hair fern, *Marsilea*, etc.). When it is an **ectophloic siphonostele,** the xylem has the form of a hollow cylinder surrounding a central pith but there is phloem only on the outside (e.g., *Osmunda*—royal fern; also characteristic of dicotyledons and gymnosperms). When there are several strands, each one of which is a

protostele, it is called the **polystele** and these strands are usually arranged in a circle so that there is a pith at the centre and cortex outside (e.g., *Pteris*, etc.).

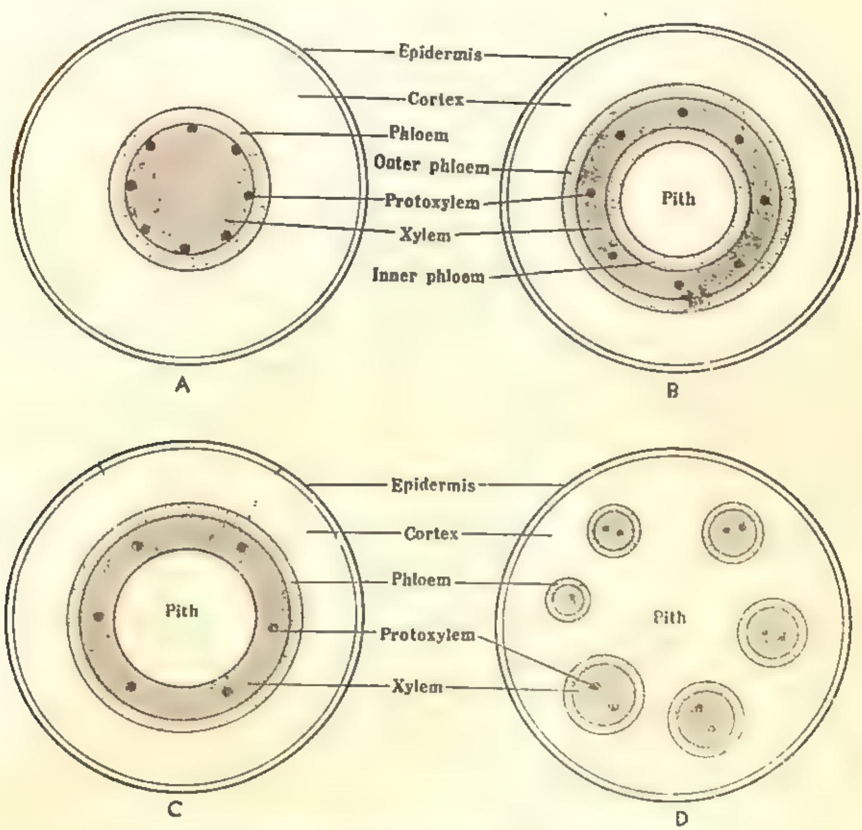


Fig. 285. Different kinds of steles in Pteridophytes. A, Protostele; B, Amphiphloic siphonostele; C, Ectophloic siphonostele; D, Polystele.

Origin of the Pteridophytes

The question of the origin of the present-day pteridophytes is a highly debated one, as a considerable gap exists in between the pteridophytes and other plants placed lower in the scale of evolution. There are two schools of view concerning the origin of pteridophytes, one proposing an origin from algae and the other from bryophytes.

According to the advocates of an algal origin, the similarities noted between the bryophytes and the pteridophytes are not due to any phylogenetic relationship existing in between the two groups,

but these are the results of a parallel evolution. While Scott (1900), and Eames (1936) do not suggest any particular group of algae as the supposed ancestors, other workers like Church (1919), and Arnold (1947), are of opinion that the pteridophytes originated from some complex marine algae 'transmigrating' from the ocean to the land. Obviously, their idea implies that the pteridophytes evolved from the Phaeophyceae. On the other hand, Boblin (1901), Lotsy (1909), and Fritsch (1916) believe that this origin has taken place from some *Chaetophora*-like filamentous green algae. In a subsequent

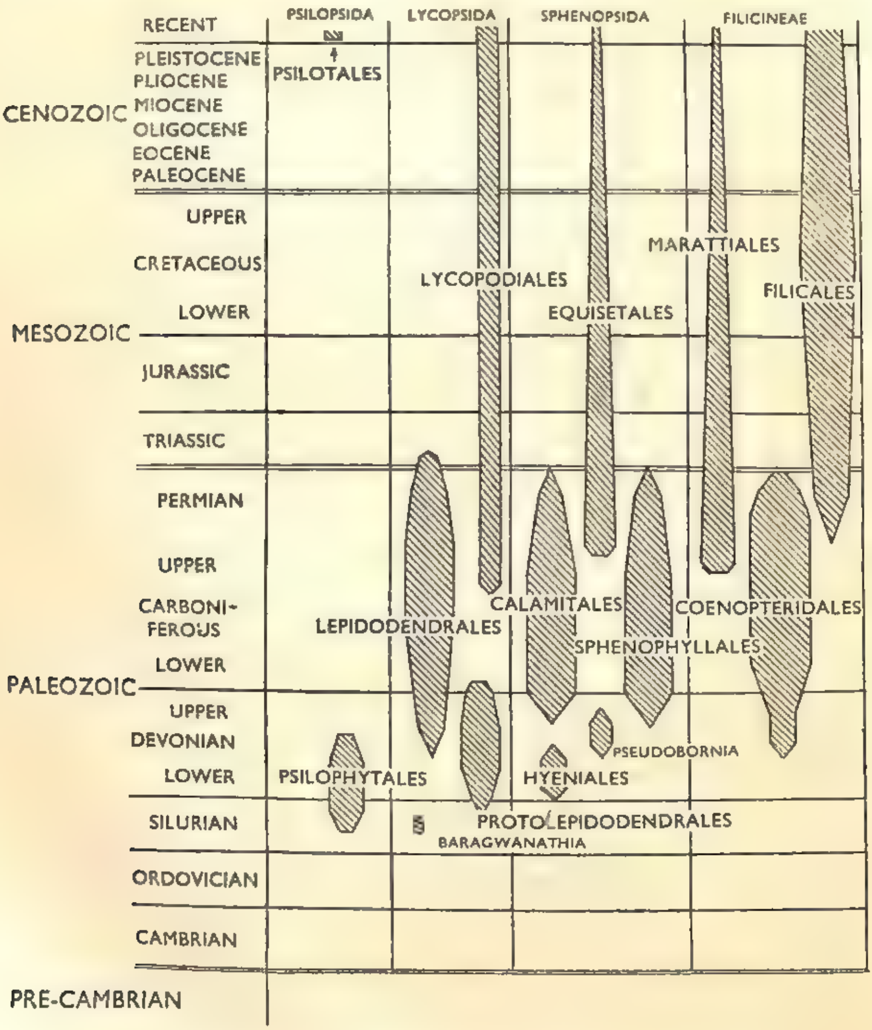


Fig. 286. Distribution of Pteridophytes in the geological periods.

publication Fritsch (1945) expressed his idea that the hypothetical ancestor was a green alga with an erect parenchymatous body possessing an isomorphic type of alternation of generations in its life cycle.

Lignier (1903), Bower (1935), and Zimmermann (1930, 1938) believe that the bryophytes and the pteridophytes are phylogenetically connected but divergently developing evolutionary lines, which have separated early from very primitive archegonia-bearing hypothetical land plants. But Campbell (1895, 1899, 1924) is of opinion that the pteridophytes have originated from the true bryophytes of the anthocerotean type. This idea was opposed at first on the ground that wide differences exist between the sporophytes of the known pteridophytes and that of the anthocerotean type. But, when the rootless; non-leafy and dichotomously branched sporophytes of the psilophytes were discovered, this objection was rendered invalid. Further, though nothing is known about the embryology of the members of the Psilophytales, but a surprisingly superficial resemblance exists in between the embryos of the living Psilotales and the Anthocerotes.

Evolution among the Pteridophytes

Among the pteridophytes the Psilophytales are the oldest as well as the most primitive, and they can be traced as far back as the Silurian. Their sporophytes were rootless and represented by either completely leafless branches or by branches having minute veinless leaves. The sporangia were borne singly and terminally at the end of a branch. From this psilophytalean stock there appeared early in different divergent directions all the present-day pteridophytes.

Classification of Pteridophytes

The Pteridophytes have been divided into *four* classes :

Class I. Psilophytineae. The sporophyte is leafless or provided with very minute leaves; roots are usually absent in the fossil forms. The sporangia are terminal and occur singly at the tips of the branches

Class II. Lycopodineae. The sporophyte is differentiated into root, stem and leaf. The leaves are minute (**microphyllous**) and usually spirally arranged.. The branching of the stem is typically dichotomous. Leaf-gaps are absent in the vascular cylinder. The sporangia are borne singly on the adaxial face of the sporophylls and contain either homospores (e.g., *Lycopodium*) or heterospores

(e.g., *Isoetes* and *Selaginella*). The sporophylls may or may not form a *cone* or *strobilus*. Sperms are usually biflagellate excepting in *Isoetes*.

Class III. Equisetineae. The sporophyte is differentiated into root, stem and leaf. The stem is provided with distinct nodes and internodes. The sterile leaves are either microphyllous or macrophyllous and are usually arranged in whorls. Leaf-gaps are absent in the vascular cylinder. The sporangia are borne in groups on the under surface of the peltate sporophylls, arranged on a special structure called the **sporangiophore** and form a distinct *cone* or *strobilus*. The sporophyte is usually homosporous. Sperms are always multiflagellate.

Class IV. Filicineae. The sporophyte is differentiated into root, stem and leaf. In some exceptional cases roots are entirely lacking. The leaves are usually large (**macrophyllous**) and are arranged spirally. Morphologically, the sporophylls and sterile leaves are alike and they never form any *cone* or *strobilus*. The sporangia are borne in groups forming *sori*, either on the margins or near about the centre on the under (abaxial) surface of the sporophylls. Leaf-gaps are present in the vascular cylinder. Sperms are always multiflagellate.

CLASS I. PSILOPHYTINEAE

The members of the Class Psilophytineae are the simplest as well as the most primitive among the pteridophytes.

Plant rootless. Sporophyte differentiated into a rhizoid-bearing rhizomatous subterranean portion and an aerial erect shoot, which is sparingly or profusely branched. Protostelic, very rarely siphonostelic. Aerial shoot leafless, sometimes beset with small, simple, veinless leaf-like structures. Sporangia usually terminal, more rarely lateral, borne singly, less frequently in pairs or in groups. Gametophytes, preserved in the living genera, are colourless and subterranean.

There is controversy of opinion as regards the origin of this Class, some suggesting that it has come from the algae, while others opine that the bryophyta has given rise to it. Whatever may be the origin, it may be considered that the remaining three Classes of the pteridophytes have come from this basic stock.

The Psilophytineae includes *two* Orders: (1) **Psilophytales,** an Order comprising fossil members only, and (2) **Psilotales,** an Order with the single family *Psilotaceae* having two living genera, *Psilotum* and *Tmesipteris*.

ORDER 1. PSILOPHYTALES

The Psilophytales are characterized in general in having a rootless, rhizomatous stem bearing rhizoids and a simple, sparsely-dichotomously branched subaerial shoot; the subaerial branches are somewhat spiny and are either leafless or provided with small, simple leaves. The sporangia are terminal in a raceme-like fashion and contain homospores; in essence the sporangia represent the enlarged tips of the branches. The stele is a protostele, which may be either a haplostele or an actinostele.

The members of the Psilophytales, which are regarded as the oldest known vascular land plants, appeared in the Silurian and existed upto the Upper Devonian, or probably early Carboniferous, but most of the records have been obtained from the Lower and Middle Devonian. The fossil remains are found in Scotland, Germany, Czekoslovakia, Norway, Australia, China and some parts of U.S.A.

Authorities differ in their opinions regarding the classification of the Order. Wettstein divides the Order into three families, Hirmer into five, and Kraussel into nine families. Arnold (1947) in his 'An Introduction to Paleobotany' recognizes the following five families: **Rhyniaceae, Zosterophyllaceae, Psilophytaceae, Asteroxylaceae,** and **Pseudosporochnaceae.**

RHYNIA

(Fam RHYNIACEAE)

Uptil now the genus comprises of 2 species only: *R. major* and *R. gwynne-vaughani* discovered from the Rhynie chert of Scotland in the Middle Devonian deposit.

Fig. 287. *Rhynia*. The plant body.

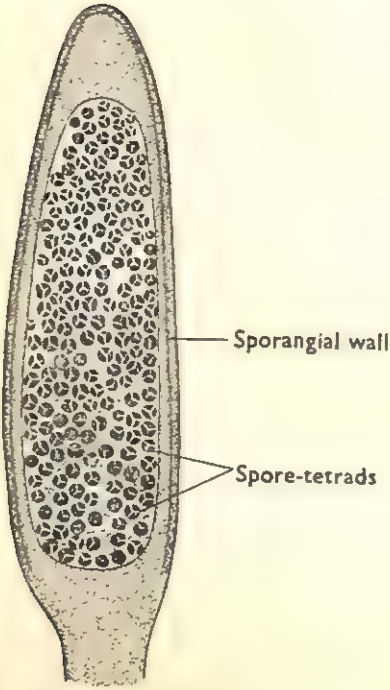


Fig. 288. *Rhynia*. L.S. of capsule.

The sporophyte

The plant body consists of a cylindrical, horizontally-growing subterranean rhizoid-bearing rhizome with dichotomously branched, leafless, aerial shoots, attaining a height of 20-50 cm. and a diameter of 1·5-6 mm. The tips of the aerial branches are gradually tapering and in some cases end in oval sporangia. The heavily cutinized spores are borne in tetrads within large cavity of the sporangium and are homospores. The sporangial wall is differentiable into two layers, one outer and the other inner, the latter probably functioning as a tapetum.

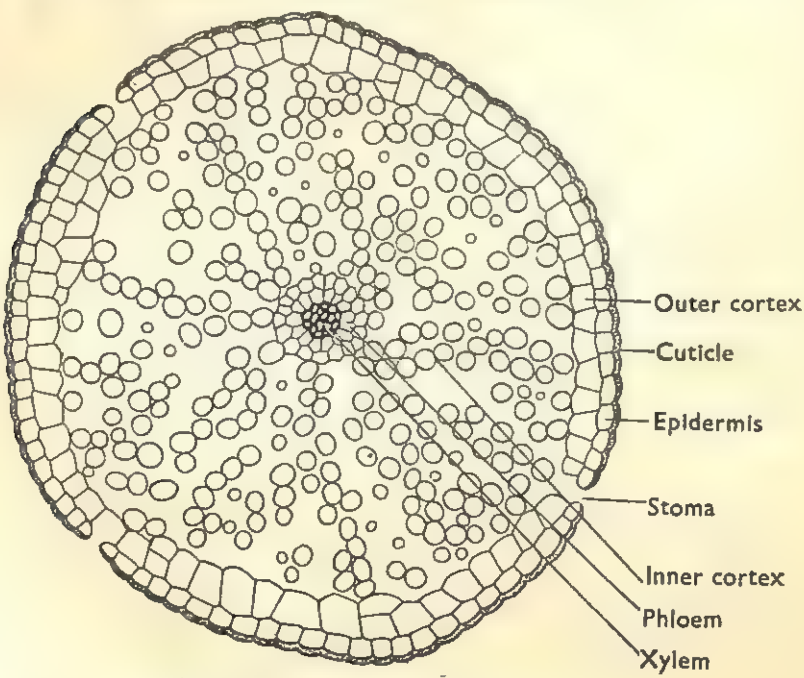


Fig. 289. *Rhynia*. T.S. of stem.

Internally, the axis is differentiated into extrastelar and intrastelar regions. The former consists of an epidermis and a thick cortex with prominent intercellular spaces; stomata occur on the epidermis. The stele is a protostele and the xylem is completely surrounded by the phloem; the xylem is composed of annular tracheids only.

Reproduction

Rhynia reproduces by vegetative method only.

In some cases small outgrowths, occasionally developing into lateral branches, have been noted to appear on the body of the aerial shoots. These branches possess independent vascular strands and are constricted at their points of attachement, which suggest that these were easily detached and thus probably formed a means of vegetative reproduction.

No record of sexual reproduction has been found as yet.

*HORNEA**

(Fam. RHYNIACEAE)

This genus possesses only one species—*H. lignieri* and is found in the Rhynie chert, either independently or in association with *Rhynia*.

The sporophyte

The plant is very similar to *Rhynia*, but is rather smaller and more delicate. The rhizome is a lobed, tuberous structure bearing rhizoids. The subaerial shoot is also dichotomously branched like *Rhynia* and is without any appendage. The sporangia are also borne at the tips of some of the branches as in *Rhynia*, but differ mainly in having a prominent sterile columella, which projects into the cavity of the sporangium from its base and extends very near to the apex. The tapetum is well defined and the spores occur in tetrads.

Internally, the rhizome is without a vascular system and consists of parenchymatous cells only, in the intercellular spaces of which some fungal hyphae are noted. The anatomy of the aerial shoot, however, represents that of *Rhynia*.

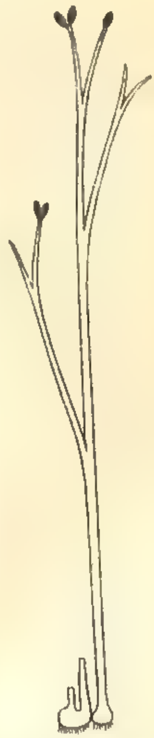


Fig. 290. *Hornea*. The plant body.

* At present called *Horneophyton*.

Reproduction

No record of sexual reproduction has yet been found.

ASTEROXYLON

(Fam. Asteroxylaceae)

So far only two species—*A. mackiei* and *A. elberfeldenes* have been discovered, the former from the Rhynie chert in association with *Rhynia* and *Hornea*, and the latter from the Middle Devonian of Germany.

The sporophyte

The plant body consists of a rootless, dichotomously branched, prostrate rhizome, bearing erect, subaerial, leafy, branched shoots. Some of the smaller branches of the rhizome penetrate into the substratum, become leafless and repeatedly forked; these probably behave as the absorptive organs of the plant. The leaves are closely crowded and possess stomata, but those at the base of the stem are rather smaller and scale-like. In general habit, the plant body of *Asteroxylon* can be compared with that of the species of the living genus *Lycopodium*. The sporangia, in actual attachment with the stems, have not been found, but certain associated fragments of

Fig. 291. *Asteroxylon*. The plant body.

leafless, dichotomous branches bearing terminal sporangia, are regarded as belonging to this genus. These sporangia are pyriform and attached to the tips of the branches by their narrow ends. Each sporangium is provided with a simple annulus and apical longitudinal dehiscence. There is no columella within the sporangial cavity and the spores are found in tetrads.

Internally, the rhizome as well as the leafy branches are differentiated into epidermis, cortex and stele. The cortical cells contain

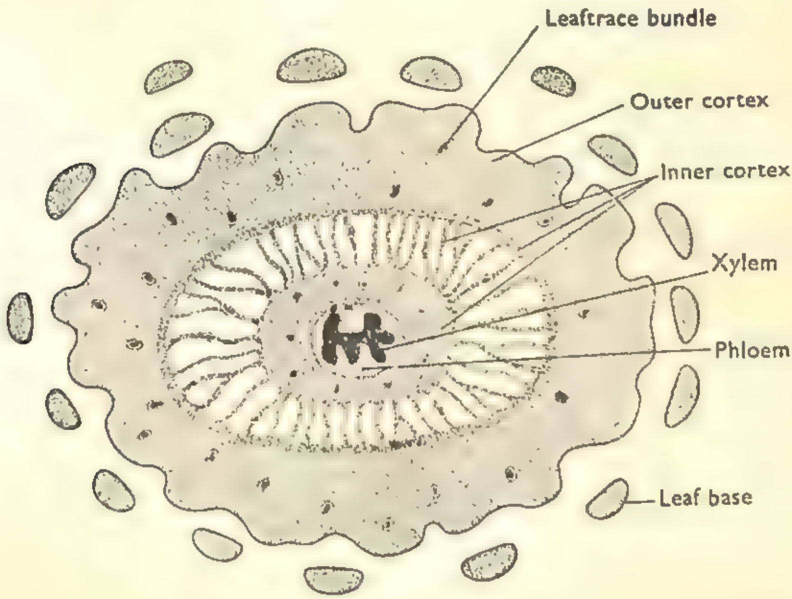


Fig. 292. *Asteroxylon*.
T.S. of stem.

fungal hyphae. The central cylinder is a mesarch actinostele with 4-10 rayed xylem. Practically speaking, the whole of the xylem mass is composed of spiral tracheids, though occasionally annular, scalariform and pitted tracheids are noted.

PSILOPHYTON

(Fam. PSILOPHYTACEAE)

This Devonian genus is widely distributed in several countries of Europe as well as in Canada and United States. The remains are generally fragmentary in nature.

The sporophyte

The plant body is small and possesses a prostrate, rootless but rhizoid-bearing rhizome, which gives rise to dichotomously branched subaerial shoots; the branching is more vigorous than that of *Rhynia*. The tips of the branches are, in some cases, circinately coiled. The major portion of the subaerial part of the plant is curved with short, rigid, spinescent emergences. As in other genera, the sporangia are borne terminally and singly at the ends of the bifurcating branches. These are usually ovoid to obovoid in shape and with a rounded or acute apex. The sporangial jacket is several celled in thickness and the spores, though varying in size, are apparently homosporous.

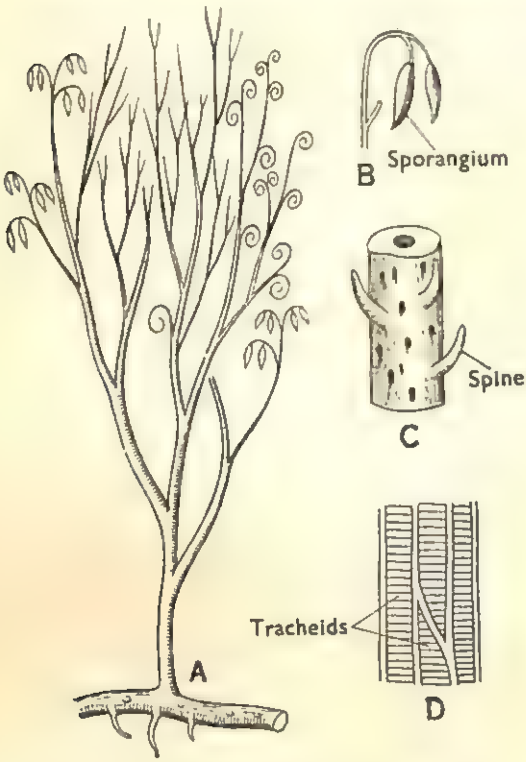


Fig. 293. *Psilophyton* (after reconstruction).

ORDER 2. PSILOTALES

The Order Psilotales is characterized by a rootless, dichotomously branched sporophyte, which is partly underground and partly subaerial. The latter part may be leafless or leafy. The sporangia are in diads (e.g., *Tmesipteris*) or triads (e.g., *Psilotum*). The gametophytes are entirely subterranean.

The members of this Order are known only in the living condition. *Psilotum* is found in the tropical and subtropical regions, but *Tmesipteris* is somewhat restricted to Australia, New Zealand, Indonesia and some other islands in the Pacific ocean.

PSILOTUM

(Fam. Psilotaceae)

Psilotum has two species: *P. nudum* (=*P. triquetrum*), which is erect and *P. flaccidium*, which is lax and pending, and grows epiphytically. The common Indian species of *Psilotum* is *P. triquetrum*.

Psilotum is a rootless, slender plant 20-100 cm. in length. The rhizome is covered with hair-like absorbing organs and frequently contains a mycorrhizal fungus. During the course of undergoing repeated dichotomous branching, the tip of any dichotomy comes out of the soil and develops into a subaerial shoot. These shoots are flattened or ridged, green in colour and are provided with minute, awl-shaped, scaly appendages in the upper portions only.

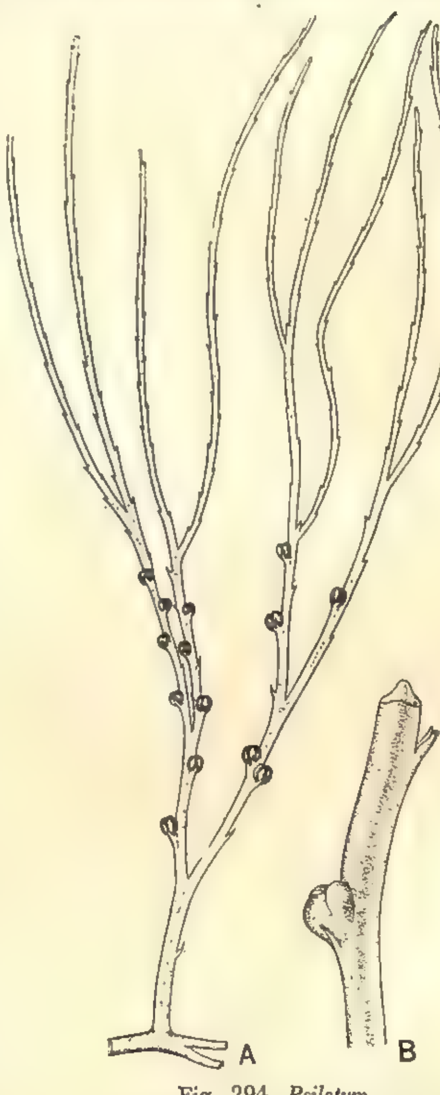


Fig. 294. *Psilotum*.
A, A portion of the plant; B, Same showing sporangium (magnified).

Internally, the subaerial shoot of *Psilotum* consists of an epidermis, interrupted frequently by stomata, below which there are a few layers of chlorenchyma cells. The cortex is differentiated into an outer sclerenchymatous and an inner parenchymatous zone; the cells in the latter region are without any intercellular space. A typical endodermis separates the stele from the extrastelar tissues. The stele is an actinostele with 5-6 rays; the xylem is exarch. Typical phloem tissue has not been demon-

strated. A slight secondary growth may take place in some cases.

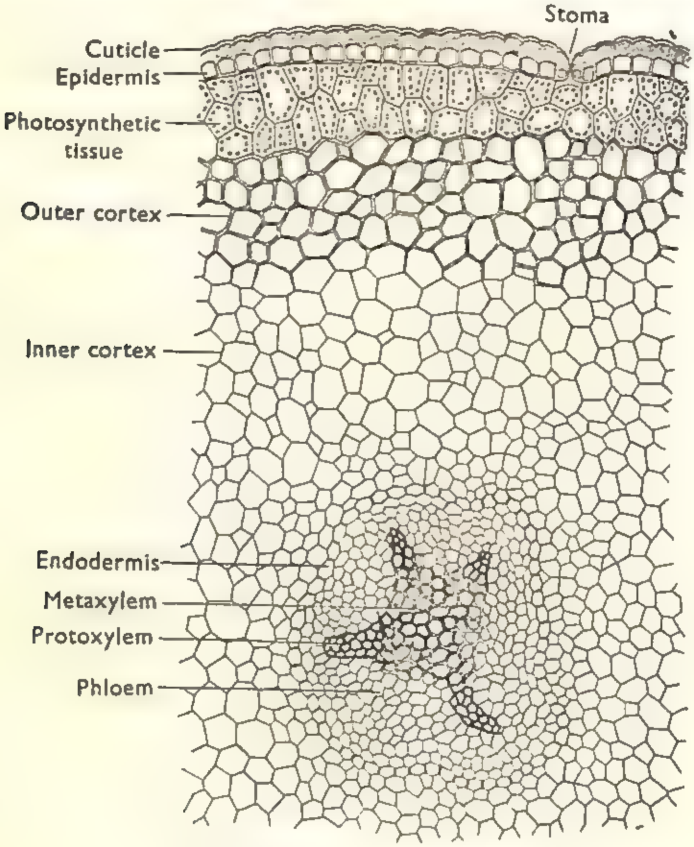


Fig. 295. *Psilotum.* T. S. of stem.

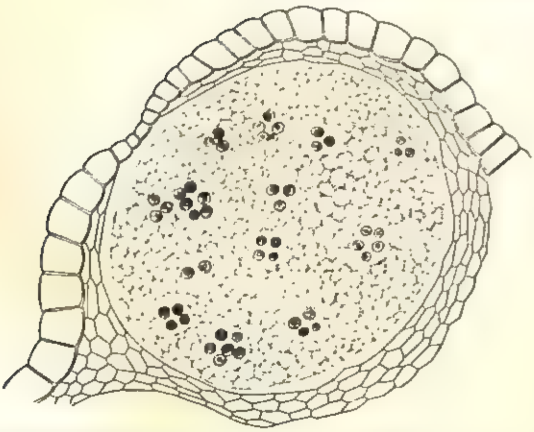


Fig. 296. *Psilotum.* T.S. of a sporangiophore (in part).

Though fertile and sterile regions cannot be strictly demarcated out, yet generally the **sporangia** are borne in triads on minute stalks in the axils of bifid scales. There is a good deal of controversy as regards the morphological nature of the sporangium; some

regards it as a **synangium** (a group of sporangia fused together), while others regard it as a single septate sporangium. A large number of sporogenous cells are produced from a single archesporial cell. Some of these sporogenous cells develop into spore mother-cells, which finally undergoing reduction divisions give rise to spore tetrads.

In some cases *Psilotum* may reproduce vegetatively by the formation of **gemmae** developed on the rhizoids.

The gametophyte

A spore on germination develops into the gametophyte, which is minute, brown in colour and perfectly subterranean and saprophytic in habit. It is irregularly cylindrical, somewhat dichotomously branching and thoroughly covered with unicellular rhizoids. The cells of this **prothallus** are filled with a symbiotic fungus. The gametophyte is monoecious.

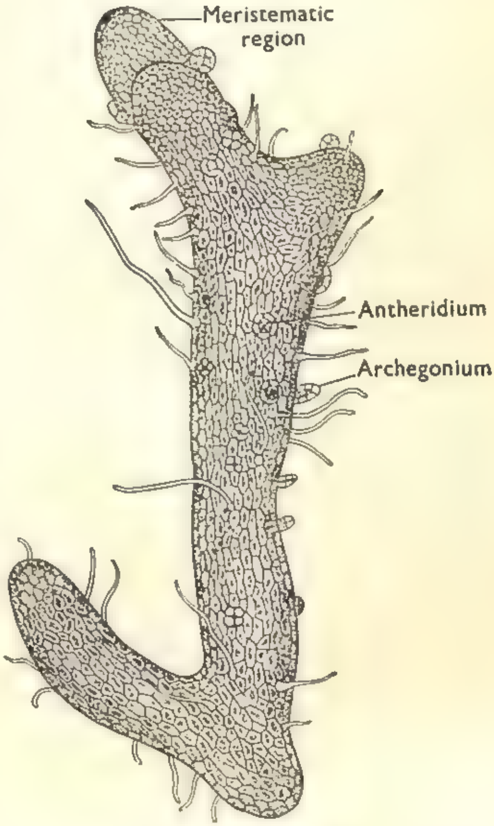


Fig. 297. *Psilotum*. The gametophyte.

The **antheridia** usually develop earlier than the archegonia. These are spherical in outline with an antheridial jacket, which is single layer thick. Mature antheridia project above the gametophyte, and each one bears numerous spiral, multiflagellate sperms.

The **archegonia** are also projecting and formed from the superficial cells of the prothallus. The neck canal cells are probably two in number and within the venter there are ventral canal cell and egg cell.

The new sporophyte

The development of the new sporophyte starts with the first division of the zygote, which is transverse, (i.e., a plane at right angles to the long axis of the archegonium) or very nearly so. From the outer part develops the axis, while the inner one gives rise to the *foot* of the embryo. This foot is very clearly distinguishable during the early stages of development. It enlarges downwards and sends out finger-like haustorial branches, which penetrate into the body of the adjoining gametophyte. Ultimately, when the young sporophyte becomes independent of the gametophyte for its food supply, the foot gets dissociated from the sporophyte and attaches itself to the gametophyte.

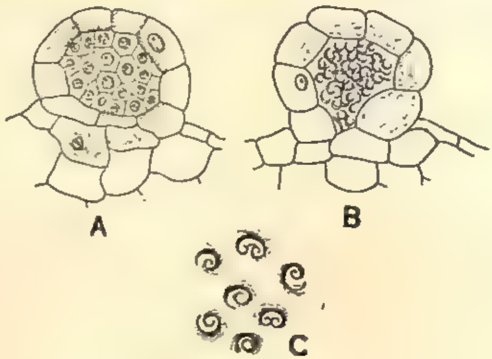


Fig. 298. *Psilotum.*
A—B, Antheridium in different stages of development: C, A few spermatozoids.

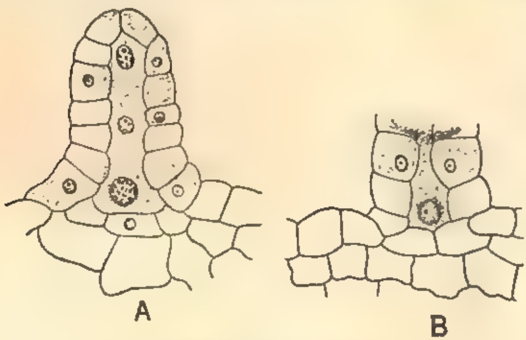


Fig. 299. *Psilotum.*
A—B, Archegonia in different stages of development.

CLASS II. LYCOPODINEAE

The Class Lycopodineae consists of an assemblage of antiquities. It is believed that they arose in the early Palaeozoic from Psilophytineae and reached their climax in the Middle Carboniferous and began to decline from Permian onwards; the Mesozoic rocks contain very few remains of the ancient lycopods. The present-day flora is represented by only 4 genera: *Lycopodium*, *Phylloglossum**,

* Excepting *Phylloglossum* all the other genera have been found in the fossil state.

Selaginella, and *Isoetes*, all of which are insignificant herbs, while some of their ancestors were tall trees.

Sporophytes differentiated into stems, roots and leaves. Leaves microphyllous, arranged spirally in opposite pairs or in whorls (?) and without any leaf gaps. Protostelic, siphonostelic, or polystelic. Sporophylls with adaxial sporangia situated near the bases of the sterile regions, or they may occur in the strobili.

For the sake of convenience, the class Lycopodineae has been divided into 5 Orders: (1) **Lepidodendrales,** (2) **Lepidocarpales***, (3) **Lycopodiales,** (4) **Selaginellales,** and (5) **Isoetales,** of which the first two Orders are found only in the fossil state.

ORDER 1. LEPIDODENDRALES

The Lepidodendrales form one of the major plant groups of the Palaeozoic era. The plants were tall trees, 30-40 metres in height, with a straight columnar trunk about 1-2 metres in diameter, and bearing dichotomously dividing branches, covered with numerous linear or acicular leaves. The subterranean portion is also dichotomously branched and so very similarly constructed in different genera that they have been placed under a single form genus† *Stigmaria*‡.

Fig. 300. *Stigmaria*.
Base of a lepidodendroid with a thick, tapering, dichotomously branched root.

Plants of tree-like habit, heterosporous. Secondary growth by means of cambium. Protoxylem exarch. Leaves microphyllous with one vein, excepting *Sigillaria*, where there are two parallel

* Prof. A. J. Eames includes *Lepidocarpales* along with *Lepidodendrales*.

†Vide General Botany

‡ The real morphological nature of *Stigmaria* is a problem uptil now. It can neither be regarded as a rhizome nor as a true root. In all probability, it is a specialized and modified shoot-system of the nature of a branch, which has functionally been modified into a root.

veins; ligulate without any leaf gap. Roots borne on rhizophores, having secondary thickening. Sporophylls on strobili, with sporangia on the adaxial surfaces.

Lepidodendrales consists of 3 families: *Lepidodendraceae*, *Sigillariaceae* and *Bothrodendraceae*. The members of this Order are usually found from the Upper Devonian to the Triassic.

LEPIDODENDRON

(Fam. LEPIDODENDRACEAE)

Lepidodendron is the best known genus of the Palaeozoic and is with more than 100 species. It appeared in the Late Devonian, flourished most luxuriantly in the Carboniferous and probably declined during the Late Permian.

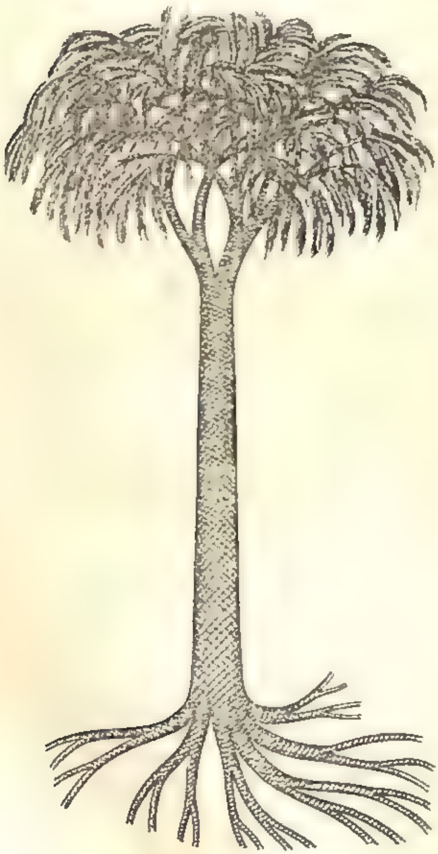


Fig. 301. *Lepidodendron* (after reconstruction). (*Redrawn after Hirmer.*)

The sporophyte

The plant is a large tree with stigmarian root-system and a straight trunk, which remains unbranched for a considerable height and then gives rise to freely dichotomously dividing branches. The leaves are simple and deciduous, acicular to linear in shape, and ligulate. These are borne either spirally or in alternating whorls. The pyramidal leaf bases are persistent in nature and form the **leaf cushions,** which have got a great taxonomic importance. The leaf base possesses a single, small, median vascular strand, flanked on both sides by a strand of

parenchymatous cells forming the **parichnos.** The parichni run parallel to the vascular strands for some time but ultimately become lost in the mesophyll tissue; these are supposed to be associated with the intake of air and its circulation through the body of the plant.

Fig. 302. *Lepidodendron*. A portion of the stem showing leaf cushions.

Internally, the stem can be differentiated into extrastelar and intrastelar regions. The cortex is very thick and is characteristically differentiated into: (1) a parenchymatous inner cortex, (2) a secreting zone, (3) a homogeneous middle cortex, similar to the inner one,

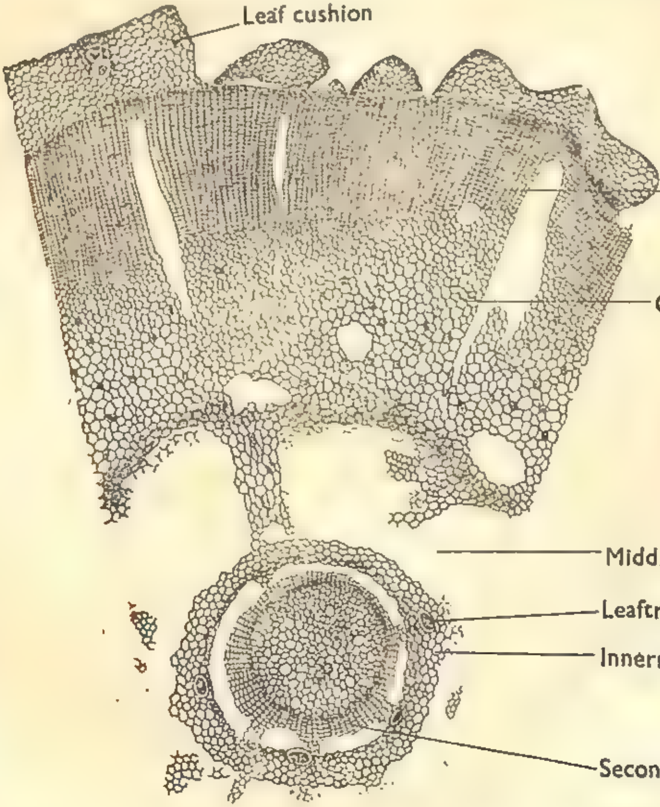


Fig. 303. *Lepidodendron*. T.S. of stem (in part).

and (4) an outer cortex composed of thin- and thick-walled cells. The stele is either a protostele or a siphonostele with exarch and polyarch xylem. In some cases, secondary growth has been recorded

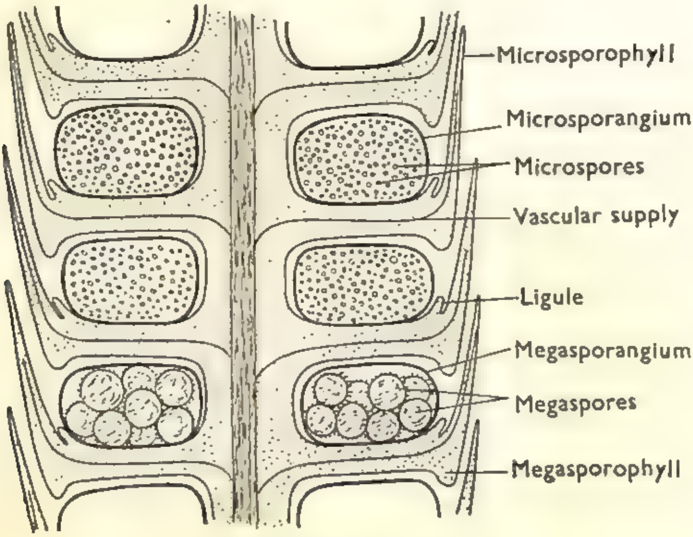


Fig. 304. *Lepidostrobus*.
L.S. of strobilus (in part).

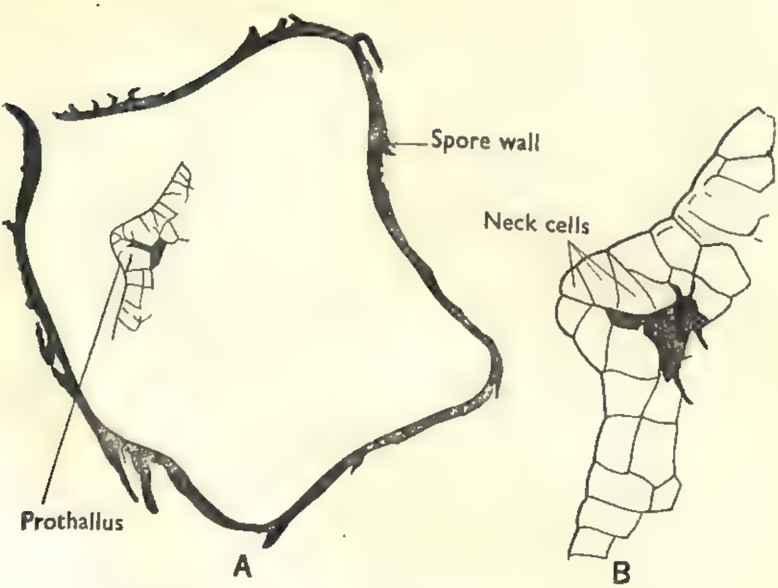


Fig. 305. *Lepidostrobus*.
A, Female gametophyte; B, An archegonium.

in the intrastelar region. The periderm is formed very early and may appear even before the intrastelar secondary thickening.

Numerous fossil lepidodendroid cones have been discovered and these are usually referred to the form genus *Lepidostrobus*. The cones are cylindrical or elliptical in outline, about 3·30 cm. in length and 2·6 cm. in breadth; these are usually slightly tapering both at the apex as well as at the base. The sporophylls are either spirally arranged or whorled, and standing out approximately at right angles from the central axis. Each sporophyll bears a ventral sporangium, whose wall is made up of a single layer of prism-shaped cells. The sporangia contain either microspores or megaspores.

The gametophyte

No male gametophyte has yet been recorded, but Gordon (1910) discovered cellular female gametophytes bearing archegonia; this suggests a possible relationship with the living *Selaginella*.

SIGILLARIA

(Fam. SIGILLARIACEAE)

Sigillaria, the 'seal tree', is another important Palaeozoic lycopod found in Europe and America.

The sporophyte

The stem is arborescent like *Lepidodendron*, but branching is less profuse and the leaves are rather longer. In general appearance the plant looks somewhat like *Dracaena*, *Cordyline*, etc. The presence of the persistent leaf cushions in *Sigillaria*, as in *Lepidodendron*, is also a prominent feature; the cushions of the former genus, however, are hexagonal or rounded and stand in more prominently raised vertical rows.

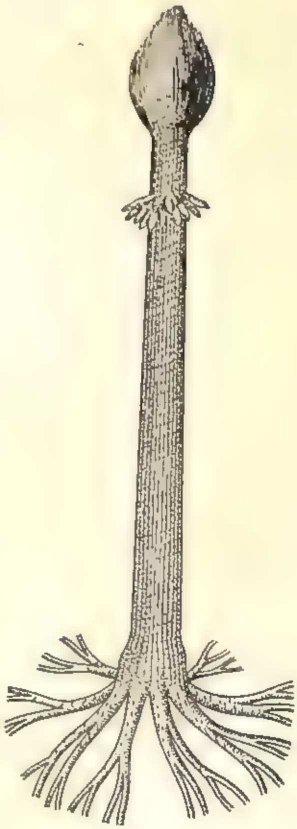


Fig. 306. *Sigillaria* (after reconstruction). (*Redrawn after Hirmer.*)

The species of *Sigillaria* are generally placed under two groups: (1) the **Eu-Sigillariae** (plants possessing

ribbed stems), and (2) the **Sub-Sigillariae** (plants without any ribs).

Anatomically, the general plan of construction of the stem of *Sigillaria* also resembles that of *Lepidodendron*. The primary xylem is either continuous or made up of strands and the protoxylem is exarch; the tracheids are scalariform. A well-defined pith is always present. Secondary growth takes place both in the intrastelar as well as in the extrastelar regions. The tracheids of the secondary xylem are either scalariform or pitted.

Fig. 307. *Sigillaria*.
A portion of the stem showing leaf cushions.

Sigillariophyllum, the leaf of *Sigillaria*, possesses double leaf traces (like the needles of some conifers) and stomata on the ventral surface.

There are two types of fructifications, the **Sigillariostrobus** and **Mazocarpon,** suggested to be the cones of *Sigillaria*. In Sigillariostrobus, as in *Lepidostrobus*, there is a central axis which bears a number of spirally-arranged or whorled sporophylls, each with a single adaxially borne sporangium. The cones are about 16-20 cm. long and all are heterosporus. The special feature of Mazocarpon is that there are 8 saucer-shaped megaspores, arranged in two rows within the megasporangium.

More than one spore, while still enclosed within the megasporangium, attain maturity and form prothallial tissue within, thus showing an advanced condition.

ORDER 2. LEPIDOCARPALES

The sporophytes of Lepidocarpales resemble those of Lepidodendrales. The remains are found in the Carboniferous.

Vegetative characters of the sporophyte similar to those of *Lepidodendron*. One kind of sporophyll present in the strobilus. Megasporophyll with an elongated megasporangium on the adaxial side; megasporangium surrounded by an integument, a structure grown up from the surface of the megasporophyll, and containing four spores, of which only one developing into a mature female

gametophyte with many archegonia. Many microspores found in the megasporangium cavity. Female gametophyte permanently retained within the megasporangium. Development of embryo into sporophyte continued after the fall of the megasporophyll to the ground.

The Order consists of 2 families: **Lepidocarpaceae** and **Miadesmiaceae.**

LEPIDOCARPON

(Fam. LEPIDOCARPACEAE)

The genus with 3 species has been found only from the Carboniferous of Great Britain.

The sporophyte

The general appearance of the plant is similar to that of *Lepidodendron.* There are *Lepidostrobus*-like cones in which heterosporous sporangia are borne on the adaxial faces of the sporophylls. The tissue of the sporophyll lying beneath the mature megasporangium and flanking its two sides develops into an integument entirely surrounding the sporangium with a slit at its apex forming a micropyle-like structure. In a young megasporangium there are four megaspores, but in a mature one only one of these develops and the other three degenerate.

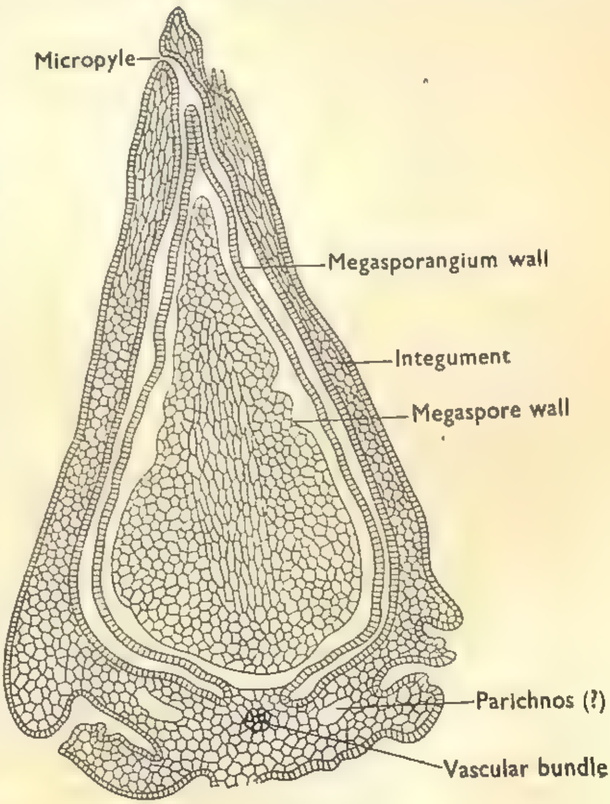


Fig. 308. *Lepidocarpon.* L.S. of a "seed".

The gametophyte

The solitary megaspore, while still enclosed within the megasporangium, develops the female gametophyte inside it. Nothing is known about fertilization. The whole structure, *i.e.*, the megasporangium, along with its permanently retained gametophyte and the integument, looks very much like a seed.

MIADESMIA

(Fam. MIADESMIACEAE)

Miadesmia is another important and well-known Carboniferous lycopod, which also bears a seed-like structure.

The sporophyte

The plant is a *Selaginella*-like delicate herb, whose internal structure also resembles that of the living genus. The sporophylls

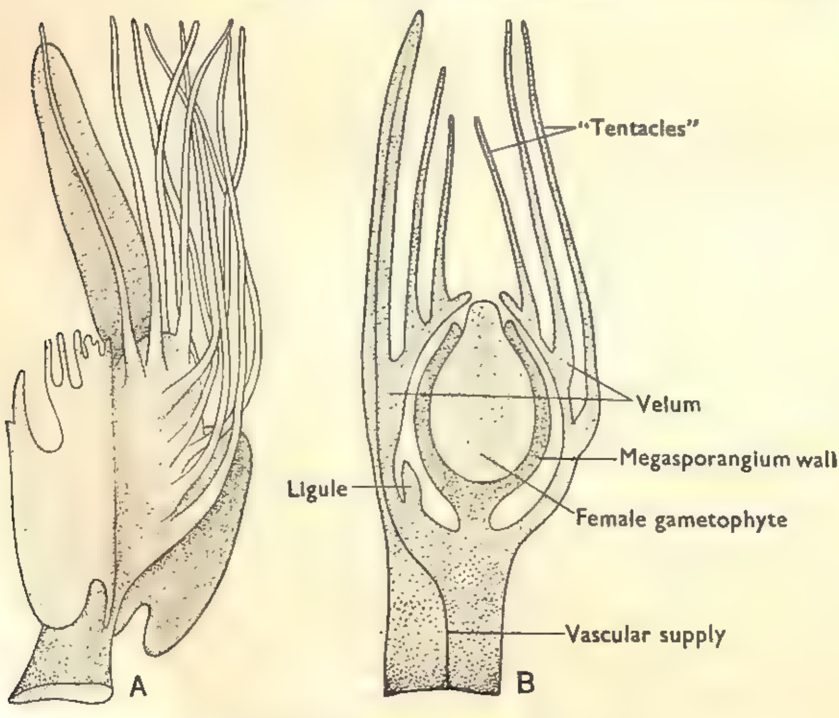


Fig. 309. *Miadesmia*.
A, A megasporophyll; B, V. S. of the same.

are borne on lax strobili, but whether a strobilus bears both micro- and mega-sporophylls or one type of sporophyll only is not known. The megasporangium contains only one functional megaspore and no degenerating sister megaspores have yet been recorded. The sporophyll, as usual, by its upturning forms an elaborate, many-lobed, integument with a terminal micropyle, which is a rounded aperture in this case.

The gametophyte

The enclosed megaspore develops into a female gametophyte, which is never shed but remains permanently confined within the megasporangium, thus giving rise to an extremely seed-like structure.

ORDER 3. LYCOPODIALES

The members of the Order Lycopodiales are distinguished from other members of the Class Lycopodineae by being *homosporous* and having *eligulate* leaves. Sporophylls may or may not be aggregated into strobili. The sporangia are developed in the **eusporangiate*** fashion. Gametophytes are partly or entirely subterranean. Spermatozoids are typically *biflagellate*. Secondary thickening in stem or root is yet unknown.

The Order consists of *two* families: (1) **Protolepidodendraceae,** and (2) **Lycopodiaceae.**

LYCOPODIUM

(Fam. LYCOPODIACEAE)

Lycopodium, commonly known as 'club-moss' and 'ground pine,' grows chiefly in tropical and subtropical forests but some species are also distributed in arctic and temperate regions.

* Superficial group of 6-12 cells in the axil of a sporophyll may act as *sporangium initial*, which by repeated divisions ultimately forms the sporangium. Each of these cells divides by periclinal wall (i.e., parallel to the surface) forming rows of outer and inner cells. The inner cells, the *primary sporogenous cells*, by repeated divisions, give rise to the sporogenous tissue, while the outer cells ultimately form the wall of the sporangium consisting of a few layers of cell. This method of sporangium development is known as **eusporangiate** method and is characteristic of all vascular plants excepting the modern ferns. As opposed to this, the **lepto-sporangiate** method of development of sporangium is one in which a sporangium is developed from a solitary initial cell.

The common Indian species of *Lycopodium* are *L. hamiltonii*, *L. phlegmaria*, *L. cernuum*, *L. selago* and *L. clavatum*.

The sporophyte

In habit all species vary widely, but all have slender, weak-stemmed, comparatively small, herbaceous or shrubby sporophytes. Many species are somewhat prostrate with stems creeping above or below the surface of the soil. Other terrestrial species have upright

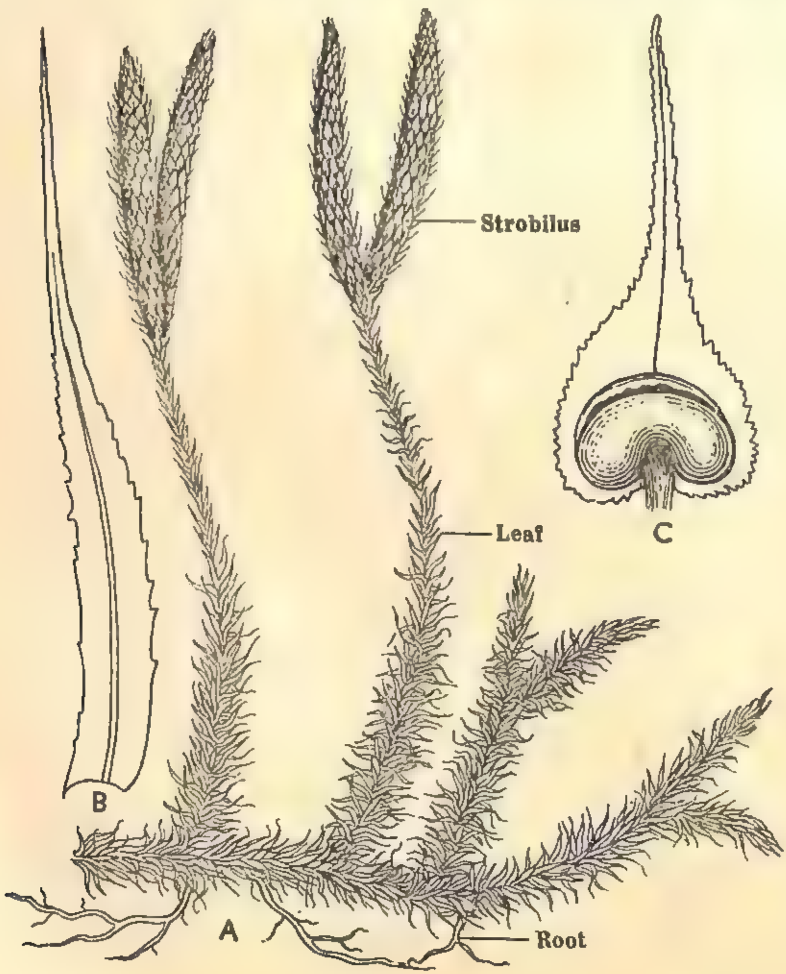


Fig. 310. *Lycopodium*.
A, A portion of a plant; B, A leaf; C, A sporophyll with a sporangium.

or semi-erect stems, which later on become more or less horizontal. Some species may also be epiphytic with pendent bodies, while still others are twining to some extent.

In the simplest case, the sporophyte has a simple stem covered with numerous, moss-like leaves, each bearing a single large sporangium on its upper side. In this sense *the whole sporophyte is a strobilus* (e.g., *L. selago*, *L. pitheyoides*, etc.). In more complex types, the sporophytes have much-branched stems whose lower leaves are sterile and act as foliage leaves, and this gradual sterilization process can be traced to more than one form, where the sporophyte is distinctly differentiated into a vegetative region bearing foliage leaves, and a reproductive region bearing the sporophylls. In such cases, the sporophylls are quite different in form from the foliage leaves and are localized and compacted to form a distinct strobilus (e.g., *L. clavatum*). These strobili are often separated from the vegetative body and are borne on slender stalks with rudimentary leaves.

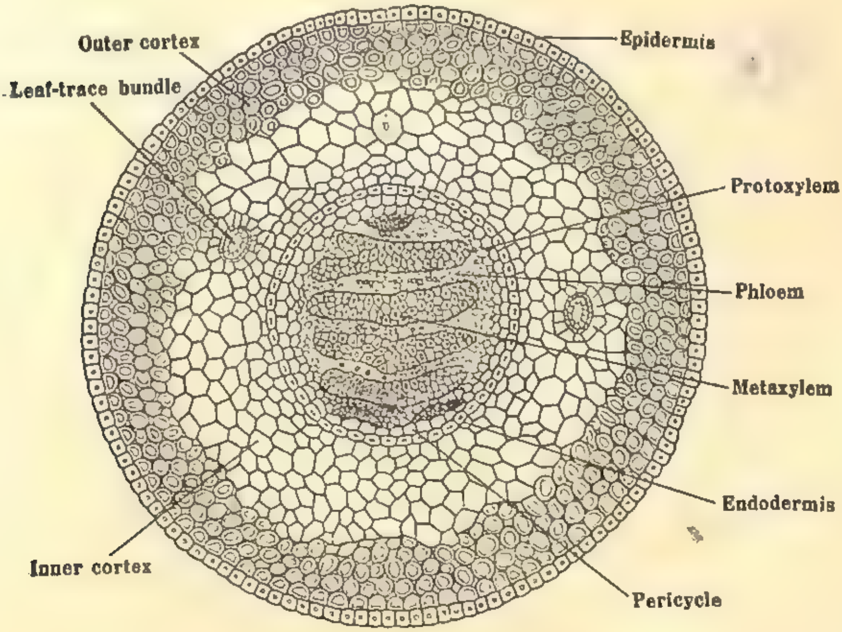


Fig. 311. *Lycopodium.*
Transverse section of the stem.

Branching of the stem is characteristically dichotomous, the two branches of a forking may be equal or unequal. The leaves are very

numerous, simple and small (usually 2-10 mm. long, sometimes up to 25-30 mm.), arranged in close spirals, whorls or opposite pairs, or the arrangement may be somewhat irregular. The primary root is short-lived but many adventitious roots arise, singly or in acropetal clusters, from the under side of the older parts of the stem and the branching is strikingly dichotomous. Root hairs are abundant and persistent in some terrestrial species and lateral roots do not develop.

A cross section of the stem shows two distinct regions, the cortex and the central cylinder or the stele. The cortex is bounded externally by an epidermis, one cell in thickness and with stomata. The cortex varies in thickness as well as in structure. In some species, it is soft and parenchymatous throughout, in others the outer or the inner portion of the cortex undergoes sclerification, while in still others the entire cortex becomes sclerified. The cortex is limited internally by an endodermis with characteristic radially thickened walls. Lying within the endodermis is the pericycle, 3-6 cells in thickness. Internal to the pericycle is the central core of vascular cylinder which is a protostele with xylem exarch. In the simplest case, the xylem appears as a star-like mass, with a variable number of rays. In between the rays lies the phloem, being separated from the xylem by narrow strip of parenchyma. In more advanced types of sporophytes, numerous furrows appear in the xylem cylinder so that the xylem breaks up into isolated strands forming plate-like lobes or mesh-like mass, with included phloem bands.

Reproduction

Lycopodium reproduces both by vegetative and sexual methods.

There are several means by which vegetative reproduction takes place: (1) Tips of lateral branches become flattened and with wing-like leaves, known as *bulbils* or *gemmae*, annually fall to the ground, take roots and form new plants. (2) The rhizome progressively grows at the apex and its older part dies, the branches become separated and form new plants. (3) In some species during winter the entire plant dies, but the apical portion behaves as a resting bud. (4) In epiphytic species, portions of plant body may give rise to new plants. (5) Roots and detached leaves of bulbils can also give rise to new individuals.

Lycopodium is homosporous and the spores are produced within large, shortly-stalked, reniform to somewhat sub-

globose sporangia, borne singly either in the axils or on the stem, a little above the sporophylls. The sporophylls are variable in form, size and colour in different species, sometimes resembling foliage leaves. These sporophylls usually become localized and aggregated to form *cones* or *strobili*, at the apex of the main stem or on lateral branches. The strobili are either stalked or sessile. The sporangium is eusporangiate in development. Within the jacket of the sporangium the *sporogenous tissue* is surrounded by a special nutritive layer known as **tapetum.** The cells of the sporogenous tissue ultimately cease to divide to form spore mother-cells, each of which by reduction division gives rise to a **spore tetrad.** *With reduction division and formation of spores, the gametophytic or haploid generation begins.* Each spore shows a weak tri-radiate ridge and its wall is either smooth or shows honey-comb or net-like thickenings.

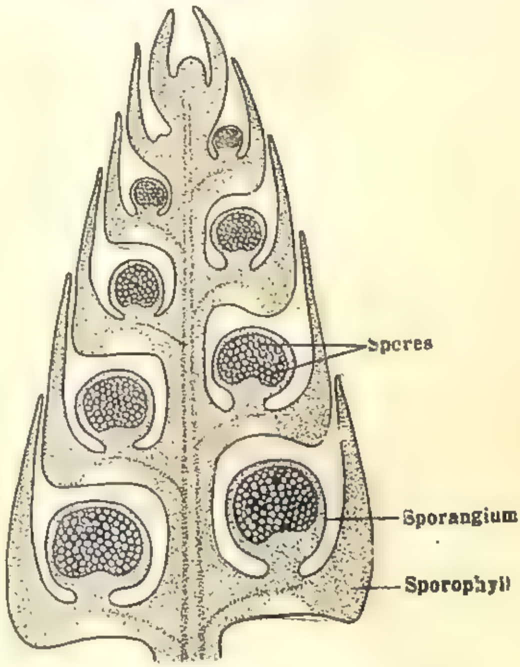


Fig. 312. *Lycopodium.* Longitudinal section of strobilus.

The gametophyte

When the spores are mature, a narrow transverse strip of cells **(stomium)** is gradually differentiated at the apex of the sporangium, which ruptures transversely and liberates the spores. Each spore, under favourable conditions, germinates and produces the gametophytic plant. There are two main types of gametophytes. In tropical species (*L. cernuum*), usually the spores after liberation germinate quickly and form short-lived gametophytes, on the surface of the ground, which are very small, green (excepting the basal portion), somewhat cylindrical to ovoid bodies with lobed

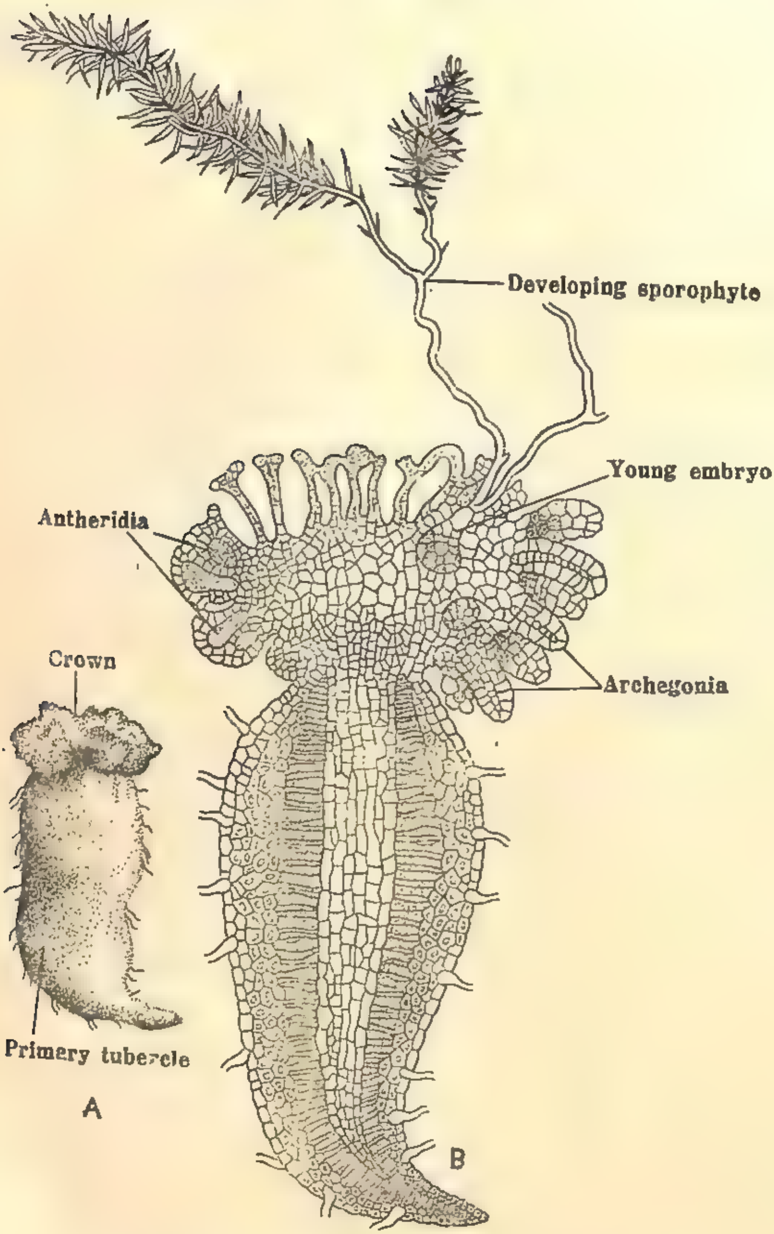


Fig. 313. *Lycopodium*.
A. A gametophyte; B, Longitudinal section of the same showing a developing sporophyte.

apices. In other cases, especially in creeping and epiphytic species (*L. clavatum*), the spores after a shorter or longer period of rest (3-8 years) germinate and form non-green, subterranean, somewhat tuberous or carrot-shaped, much larger gametophytes, sometimes much convoluted, and these grow to maturity very slowly, taking several years (6-15 years) and nourishing the young sporophytes. In other species, transitional forms occur and these gametophytes are partly subterranean with a green, lobed, aerial portion (**crown**) bearing the sex organs. Usually, both types of gametophytes are associated with an endophytic fungus forming a **mycorrhiza,** which is a prominent feature of the gametophyte.

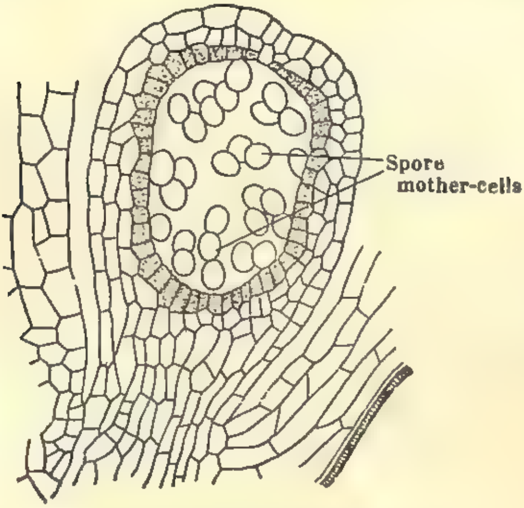


Fig. 314. *Lycopodium.*
Longitudinal section of the sporangium containing spore mother-cells.

The gametophyte of *Lycopodium* is monoecious (homothallic) and numerous sex organs, antheridia and archegonia, are borne either on the crown, or in between its lobes, or on the central cushion in flattened types of the gametophytes.

The antheridia vary in size, shape and number of spermatozoids and either project slightly or remain wholly embedded within the gametophytic tissue. There are many spermatozoid mother-cells within the single layered antheridial wall and each gives rise to a biflagellate (rarely three) spermatozoid resembling the spermatozoid of Bryophyta.

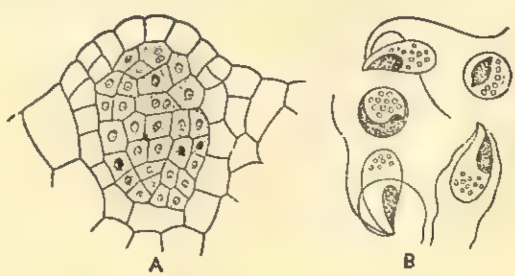


Fig. 315. *Lycopodium.*
A, An antheridium; B, Spermatozoids.

The archegonia are either short or long and embedded in the tissue of the gametophytes with their necks protruding upwards. At maturity, each archegonium contains an egg cell, a ventral canal cell and 6, sometimes 10-13, canal cells (but only one neck canal cell in shorter archegonium).

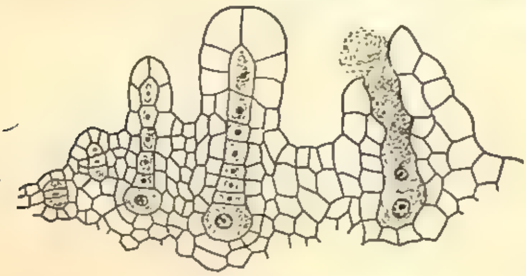


Fig. 316. *Lycopodium.*
Stages in the development of the archegonium.

When the archegonium attains maturity its neck canal cells and ventral canal cell disintegrate forming a passage open to the ovum for the spermatozoids to fertilize. The walls of the antheridium breaks up, the spermatozoids are set free, these are washed to the archegonium and one of them, finding its way through the neck, ultimately fertilizes the ovum. The fertilized ovum soon covers itself with a wall and forms the **oospore.** *With fertilization and formation of oospore, the sporophytic or diploid generation begins.*

The new sporophyte

The oospore, by repeated divisions, gives rise to an embryo consisting of a *suspensor cell*, an absorbing organ called the *foot*, the stem, a leaf and a root belated in development. From this embryo the young sporophyte gradually develops and this may be supported and nourished by the gametophyte for several years. In some cases several young sporophytes may be borne simultaneously on the same gametophyte.

ORDER 4. SELAGINELLALES

Sporophyte herbaceous and heterosporous. Usually without any secondary thickening, but in *Selaginella selaginoides* a few secondary xylem elements present. Foliage leaves microphyllous—all alike, or dimorphic, ligulate. Roots borne at the distal ends of the branches (considered to be modified axes), known as *rhizophores.* Sporophylls always aggregated into well-organized strobili. Vegetative portions of micro- and mega-sporophylls alike, but micro-

and mega-sporangia differing in size; sporangia developing in eusporangiate fashion. Spermatozoids biflagellate.

There is only *one** family included under this Order: **Selaginellaceae.**

SELAGINELLA

(Fam. SELAGINELLACEAE)

Most species of *Selaginella* inhabit damp forests of tropical climates and are distributed all over the world; some species also grow in the temperate regions. These are found in the hills and are abundantly cultivated in private gardens. Some are xerophytic and grow on rocky cliffs or dry sandy soil. They are mostly perennial, a few are small, delicate annuals.

The common Indian species of *Selaginella* are *S. rupestris*, *S. pentagona*, *S. proniflora*, *S. semichordata* and *S. megaphylla*.

The sporophyte

In general appearance, they are usually long, slender, much-branched, dorsiventral, creeping stems. All forms branch freely,

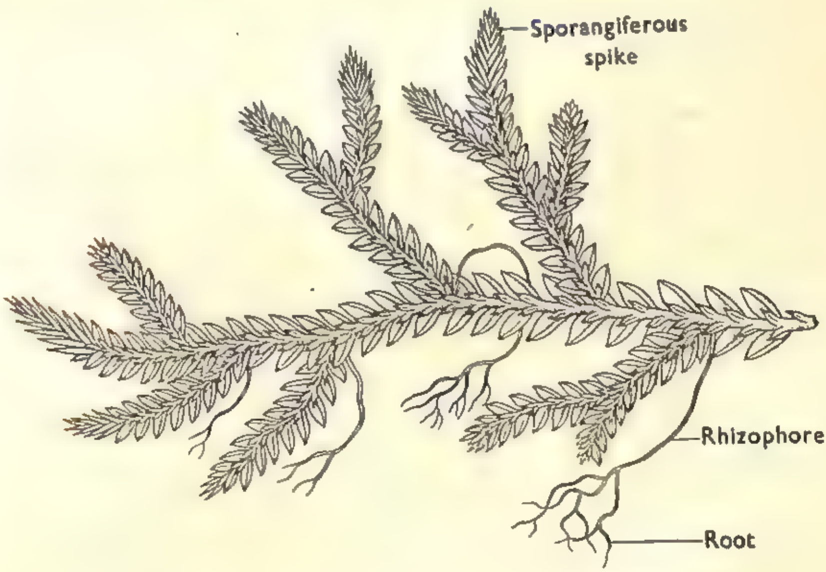


Fig. 317. A portion of vegetative body of *Selaginella*.

* According to some authorities the family Miadesmiaceae should belong to the Order Selaginellales instead of Lepidocarpales.

chiefly in one plane, and the branching is in most cases dichotomous or pseudo-monopodial.

(The stems are thickly clothed with numerous small, more or less ovate leaves, usually of two distinct kinds: some large and some small, arranged usually in four longitudinal rows,) two of which spring from the lower and two from the upper part of the stem. (The leaves of the lower surface are much larger than the upper ones, one small leaf and one large leaf arise at each node*.) (At the base of the ventral surface of the leaf, there is a membranous **ligule** which is characteristic of the *Selaginella*.)

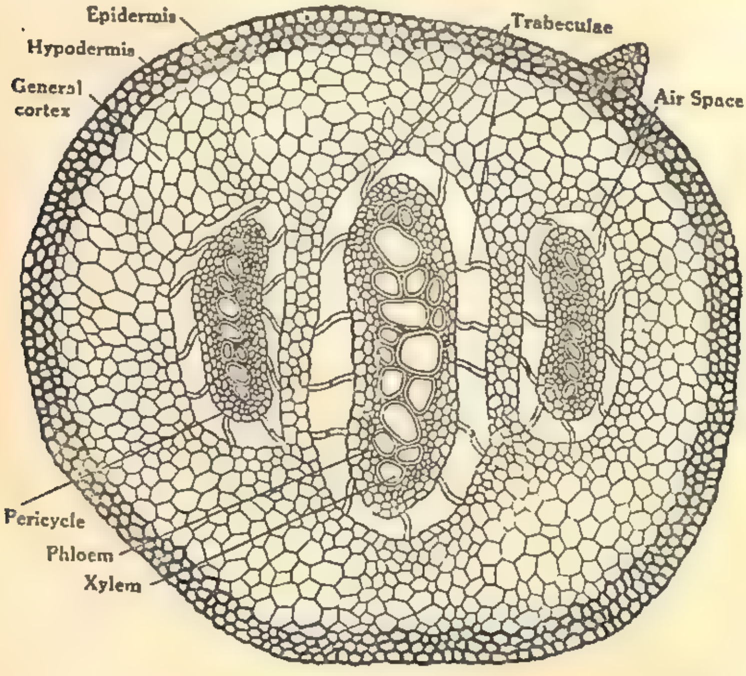


Fig. 318. *Selaginella*.
Transverse section of the stem.

The roots are mostly adventitious, because the first root dies early. The branching of the roots is dichotomous in alternate planes. At each ramification of the stem, a root-like organ, the **rhizophore**†, is developed, which on reaching the soil produces the roots there.

* In some cases the leaves are filiform and the arrangement is either in spirals or in decussate pairs.

† The morphological nature is doubtful. However, it appears to be normally a leafless stem and may sometimes bear leaves and even cones.

[A cross section of the stem shows two regions clearly differentiated into the cortex and the stele or steles. The cortex is many-layered consisting of either entirely thin-walled parenchyma or the outermost part of it being thick-walled and highly lignified (*sclerified parenchyma*), with or without intercellular spaces and is bounded on the outside by a single-layered epidermis, consisting of thick-walled cells and with a cuticle. The number of meristele ranges

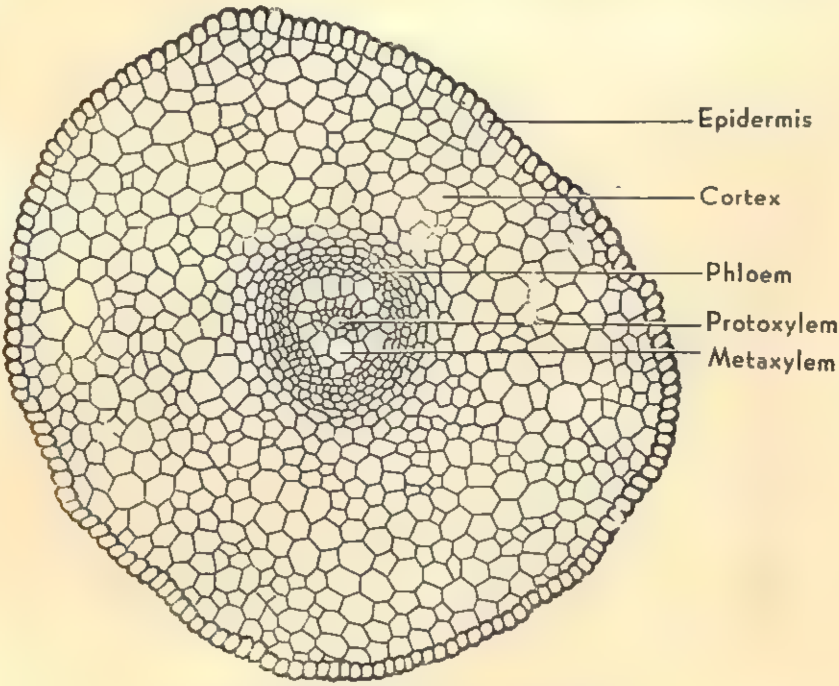


Fig. 319. *Selaginella.* T.S. of a rhizophore.

from one to three or more, each of which is surrounded by an air-space, which is bridged by radially elongated cells with prominent casparian strips, the **trabeculae,** which represent the endodermis. Surrounding each meristele there is a single layer of pericycle consisting of conspicuous parenchyma cells. The vascular bundles are hadrocentric; the xylem is exarch and diarch.) T.S of stem

A transverse section of the rhizophore shows an epidermis and a well-developed cortex enclosing the stele. The endodermis is not clearly marked out. There is a solitary protoxylem and the phloem entirely encircles the xylem.

Selaginella is heterosporous, because the asexual reproductive units, the spores, are of two kinds; the smaller ones are **microspores** and the larger ones are **megaspores,** which are produced in different kinds of sporangia. The sporangia are mostly reniform or ovoid, sometimes flattened and shortly stalked. The two kinds of sporangia differ greatly in size, the **megasporangia** being much larger than the **microsporangia.** The sporophylls bearing megasporangia are called *megasporophylls* and those bearing microsporangia are called

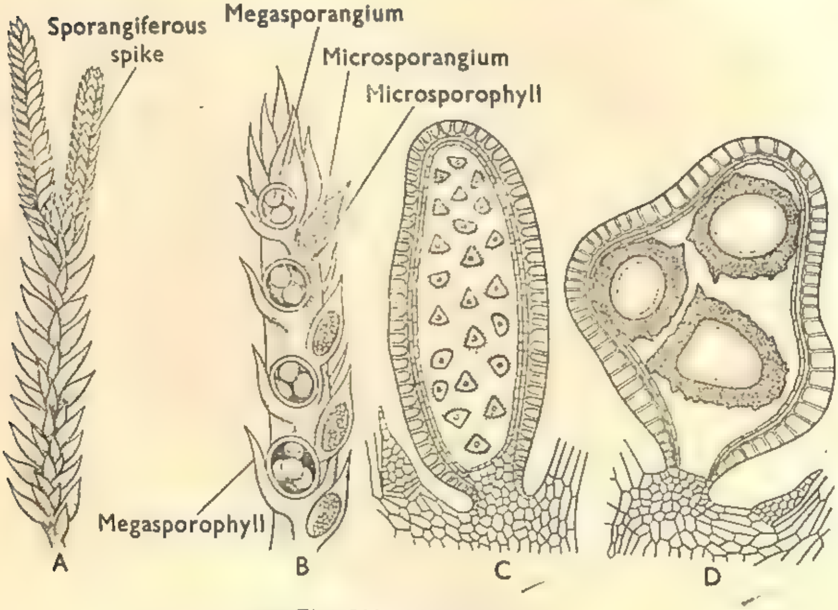


Fig. 320. *Selaginella.*
A, Sporangiferous spike ; B, V. S. of the same ;
C, Microsporangium ; D, Megasporangium.

microsporophylls. The sporophylls, which are nearly of equal size, are generally collected into more or less distinct, four-angled **cone** or **sporangiferous spike** or **strobilus.** These strobili are terminally situated at the apices of the branches. Each strobilus usually consists of both types of sporophylls, but in some species only one type of sporophylls may occur. The order of arrangement of the two types of sporophylls is variable in different species. Each megasporophyll bears in its axil a megasporangium within which occurs *only one functional megaspore mother-cell* and it gives rise

to four megaspores* due to reduction division. On the contrary, each microsporophyll bears in its axil a microsporangium containing *many microspore mother-cells*, each of which produces four microspores due to reduction division, so that many microspores occur in each microsporangium. Both types of spores are tetrahedral and the wall shows a tri-radiate ridge and ornamentations. *With redution division and formation of spores, the gametophytic or haploid generation begins.*

The gametophytes

Male gametophyte. The microspores, when still included within the microsporangium, begin to germinate but are ultimately set free by transverse rupture of the sporangium-wall. The result of germination of each microspore is a **male prothallus (prothallial cell)** which is extremely reduced to a single cell.

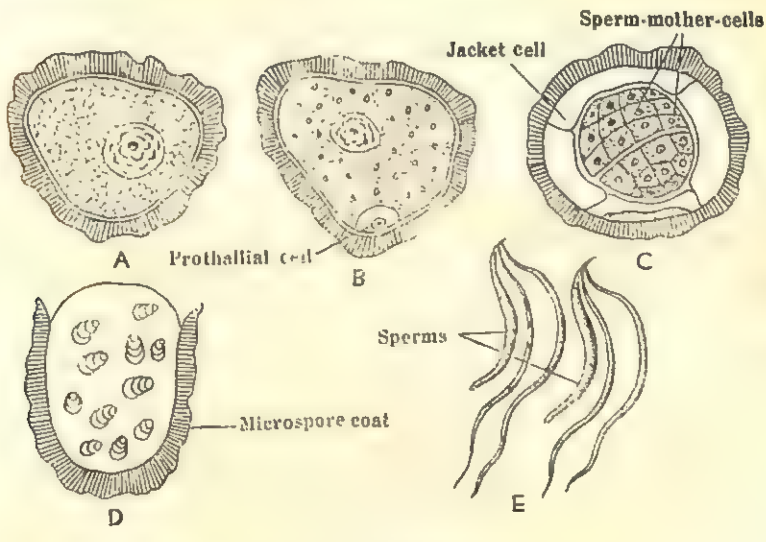


Fig. 321. *Selaginella.*
A—D, Successive stages in the development of male gametophyte and formation of spermatozoids;
E, Two spermatozoids.

It bears the so-called rudimentary *antheridium* (the *primary spermatogenous cells*—four in number) *being surrounded by a jacket of sterile cells* (*jacket cells*) and the whole remains included within

*Occasionally 8 to 40 megaspores are found in a megasporangium.

the spore-wall. From the primary spermatogenous cells about 128 to 256 *spermatozoid mother-cells* are produced. Biflagellate spermatozoids are developed from the spermatozoid mother-cells

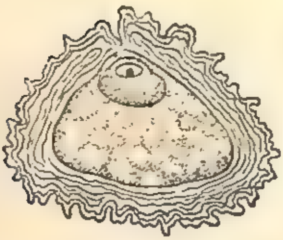


Fig. 322. A megaspore of *Selaginella* in section.

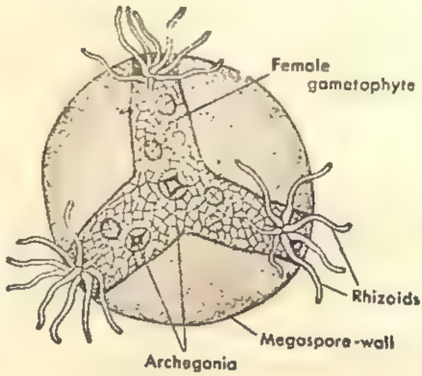


Fig. 323. Megaspore of *Selaginella* showing the female gametophyte exposed through the tri-radiate ridge.

of the so-called antheridium and these ultimately float freely in the cavity of the spore-wall. The spore-wall bursts and liberates the spermatozoids in the surrounding film of water.

Female gametophyte. Similarly, megaspores germinate before they are set free from the megasporangium. On

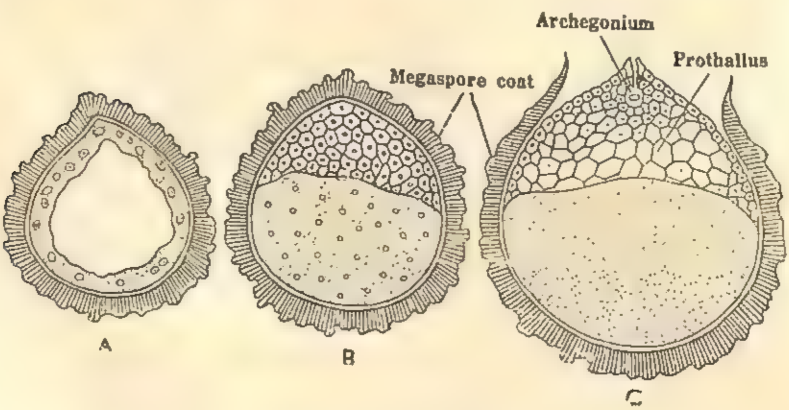


Fig. 324. *Selaginella*.
A—C, Stages in the development of female gametophyte and formation of archegonium.

germination, the spore-wall does not burst immediately and there follow within it free nuclear divisions forming a large number of nuclei, which are distributed in the general mass of cytoplasm surrounding a large central vacuole. As the nuclei increase in number, the cytoplasmic layer becomes thicker and the vacuole becomes smaller and smaller until it is completely filled up with cytoplasm. Wall-formation about the nuclei follows from the periphery near the apical region (towards the tri-radiate ridge) forming a tissue which gradually extends inwards. In some cases, after forming a tissue consisting of 3-10 layers of cells from the periphery, the wall-formation stops temporarily and the inner wall of the lowermost layer of cells becomes thickened to form so-called **diaphragm,** which separates the peripheral tissue from the non-cellular portion. The megaspores, at about this stage, are liberated from the megasporangium and the wall of each megaspore ultimately bursts along the tri-radiate ridge exposing the archegonia and part of the female gametophyte. The female gametophyte then becomes green and also develops rhizoids, which come out through the tri-radiate fissure.

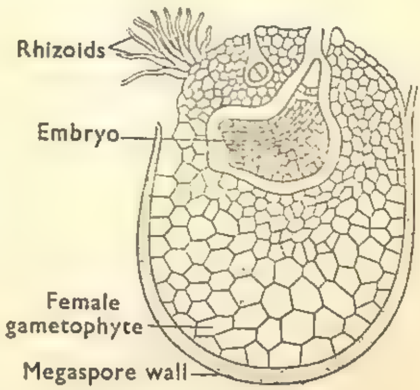


Fig. 325. *Selaginella.* A longitudinal section through the female gametophyte showing the embryo sporophyte.

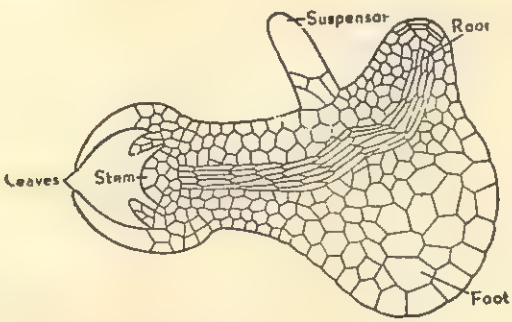


Fig. 326. Embryo of *Selaginella.*

The female gametophyte, thus ultimately becomes independent of the sporophyte but not free from the megaspore, being still

enclosed within spore-wall. Within each archegonium the *ovum* or *oosphere* develops.

When the archegonium attains maturity, the neck cells and ventral canal cells disorganize. The biflagellate spermatozoids, discharged from the antheridium of the neighbouring rudimentary male prothallus, swim towards the archegonium in dew or rain water, and ultimately one of them fertilizes the ovum. The fertilized ovum, on secreting a wall round itself, becomes an **oospore.** *With fertilization and formation of oospore, the sporophytic or diploid generation begins.*

The new sporophyte

The oospore gradually gives rise to an embryo possessing a stem, two cotyledons, a foot, a root, and a suspensor, and from this embryo the *Selaginella* plant is derived.

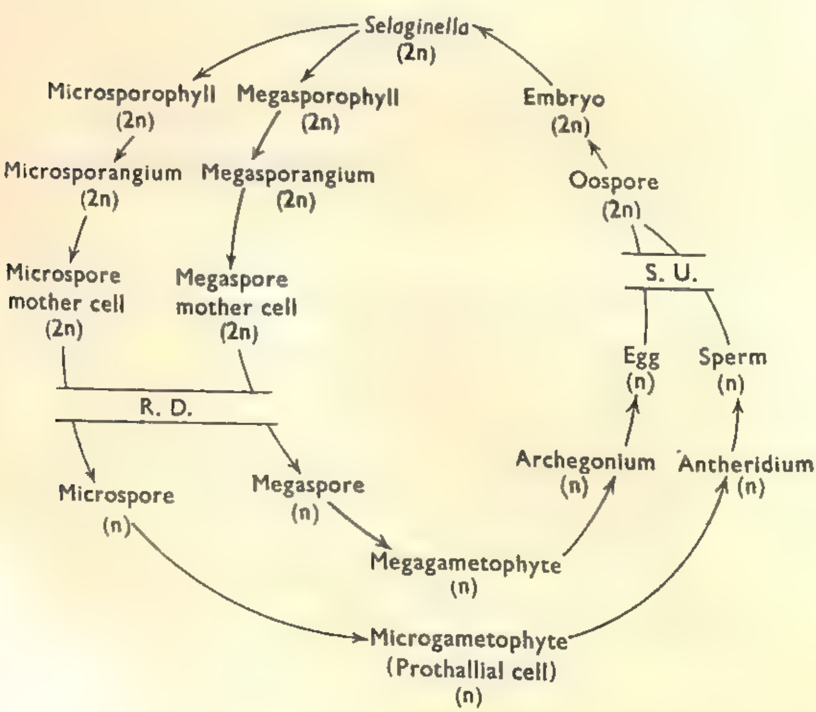


Fig. 327. Life cycle of *Selaginella*.

ORDER 5. ISOETALES

Sporophyte herbaceous, rarely small trees, heterosporous. Massive rhizophore at the base of the stem. Leaves microphyllous and ligulate. Sporophylls aggregated into strobili, or lax. Sporangia incompletely trabeculated, and developed in eusporangiate fashion. Spermatozoids, in the living genera, multiflagellate. A special type of secondary growth noted in the axis of *Isoetes*.

There are *two* families belonging to this Order : (1) **Pleuromeiaceae,** and (2) **Isoetaceae.**

PLEUROMEIA

(Fam. Pleuromeiaceae)

Pleuromeia is a plant of the Middle Triassic and has been recorded from Europe and Eastern Asia.

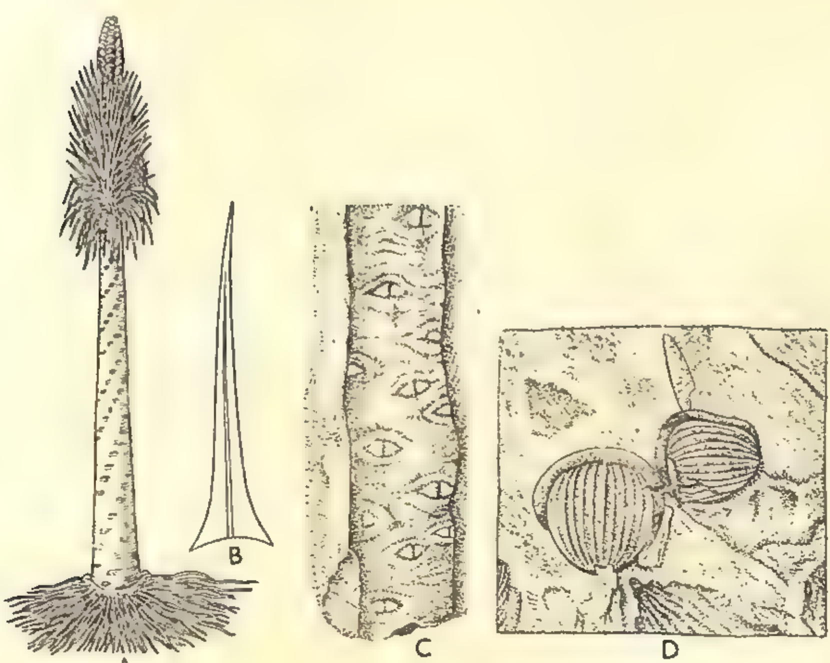


Fig. 328. *Pleuromeia.*
A, Plant (after reconstruction) ; B, Leaf ; C, A portion of stem showing leaf scars ; D, Sporophyll seen from above. (*Redrawn after Hirmer.*)

The sporophyte

The stem is an unbranched erect trunk, about 2 metres high and with a girth of about 10 cm. The upper portion of the axis is thickly covered with long, linear-lancealate, spirally arranged leaves, each having a prominent double mid vein and a broad base bearing ligule. On the other hand, the lower portion of the axis bears innumerable spirally arranged leaf scars. The base of the stem is divided dichotomously into four, six or eight short and thick lobes, covered with rootlets as in *Isoetes* and *Lepidodendron.*

In the subaerial portion of the axis the stele is an actinostele with exarch protoxylem. The secondary thickening is noted in the extrastelar region only, where a thick periderm is produced.

Pleuromeia is heterosporous, two kinds of spores being borne by the plant : the reniform microspores and the tetrahedral megaspores. The spores are borne within the sporangia, which in their turn are borne apparently on the abaxial sides of almost equal-sized sporophylls. The sporophylls, which are either oval and without any tip, or reniform or circular, are aggregated together on the axis giving rise to a solitary terminal cone.

ISOETES

(Fam. Isoetaceae)

A great majority of the species of *Isoetes*, commonly known as 'quillworts' are hydrophytes which grow in water or on swampy lands.

A few species, however, grow in habitats that are completely dry for greater part of the year. The common Indian species of *Isoetes* are *I. coromandeliana* and *I. sampattikumarini.*

The sporophyte

Isoetes suggests the appearance of a tufted grass, which consists of a very short, two- or three-lobed, tuberous axis densely covered by rosette of overlapping bases of stiff awl-shaped leaves. From the lower surface of the stem many dichotomously branched roots develop. The leaves are unique in structure, being arranged in a close spiral on the upper surface of the stem. *Each leaf is a sporophyll*, the outermost and lowermost leaves being sterile; successively

within these are sporophylls with mature and immature sporangia. In this sense *the entire plant body suggests the construction of a strobilus.* Each leaf consists of a basal sporangium-bearing region and a terminal foliage region. The awl-shaped foliage portion of the leaf contains within it four cylindrical air chambers, which may be transversely septate at intervals.

At the junction of the blade and basal portion of the leaf, there appears on the adaxial side a **ligule** being socketed in a small pit. Below this ligule the broad sporangium-region occurs. There is a single flattened sporangium on the adaxial face of each leaf. This sporangium is situated within a depression in the leaf-base and is more or less completely or incompletely shut off from the outside by a curtain of tissue (**velum**) arising just below the ligule.

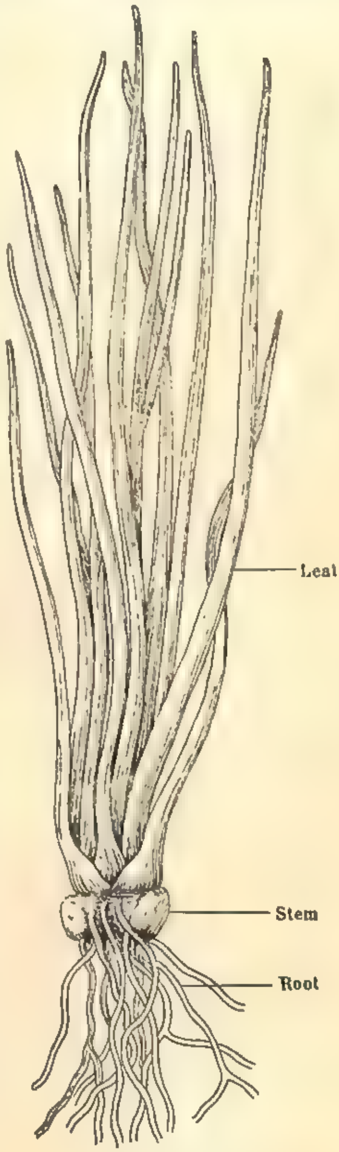


Fig. 329. *Isoetes*. An entire plant.

The anatomy of the stem has been interpreted variously as it appears to be somewhat confusing. The stem is so much compressed that the vascular cylinder appears to be a little more than a vascular plate and is a **protostele.** The xylem elements, however, do not completely fill up their region and the phloem elements are not completely recognizable. Some sort of secondary growth takes place by means of cambium.

Isoetes is heterosporous. Both microspores and megaspores are produced in different types of sporangia, microsporangia and megasporangia, borne on microsporophylls and megasporophylls respectively. The method of development of both types of sporangia

is somewhat alike in early stages. Within each sporangium a large mass of *sporogenous tissue* (upto 10,000-15,000 cells) is developed. At this stage the differences resulting in heterosporous conditions start. In those sporangia, which are destined to become microsporangia, differentiation of the sporogenous tissue begins. Some of the cells of the sporogenous tissue form alternating plates of sterile cells (**trabeculae**) across the sporangium with fertile cells, which function as microspore mother-cells. In those sporangia which are to become megasporangia, the trabeculae appear to be more massive and out of the thousands of sporogenous cells only 42-75 megaspore mother-cells are fertile, others performing nutritive function.

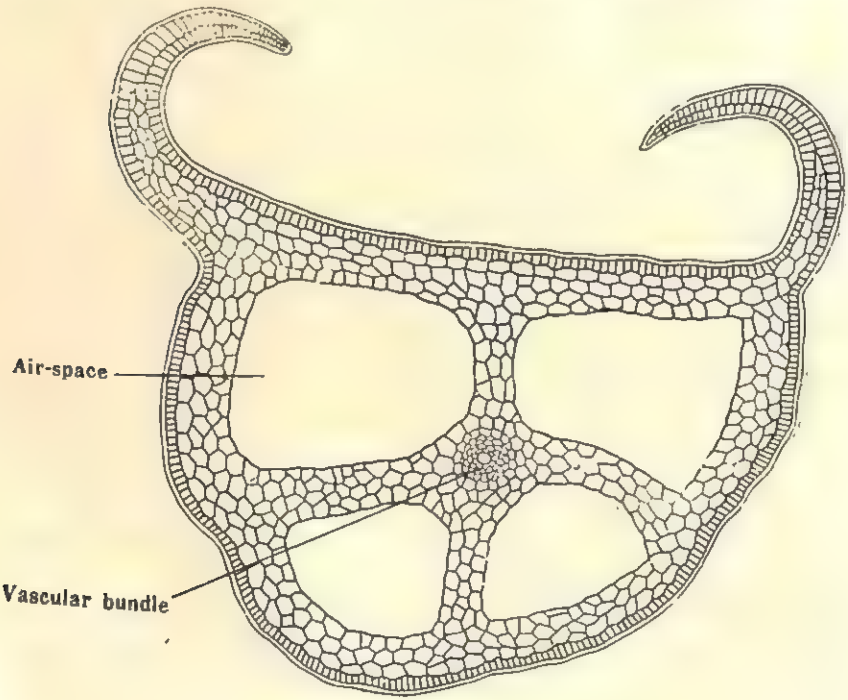


Fig. 330. *Isoetes*.
Transverse section of leaf.

Reduction division of the spore mother-cells follows and from each four spores are produced with the initiation of the gametophytic or haploid generation. The total output of microspores in a single microsporangium is 15,000-300,000 and that of megaspores in a single megasporangium is 150-300. At maturity, the sporangia are

indehiscent in most cases and both types of spores are ultimately liberated by the death and decay of the sporophylls.

The gametophytes

Male gametophyte. The microspores, after liberation, germinate immediately and form male gametophytes within a few days. The nucleus of each microspore divides and the microspore is divided asymmetrically into a small **prothallial cell** and a large **antheridial initial cell.** The prothallial cell remains undivided, but the antheridial initial divides repeatedly and ultimately forms a

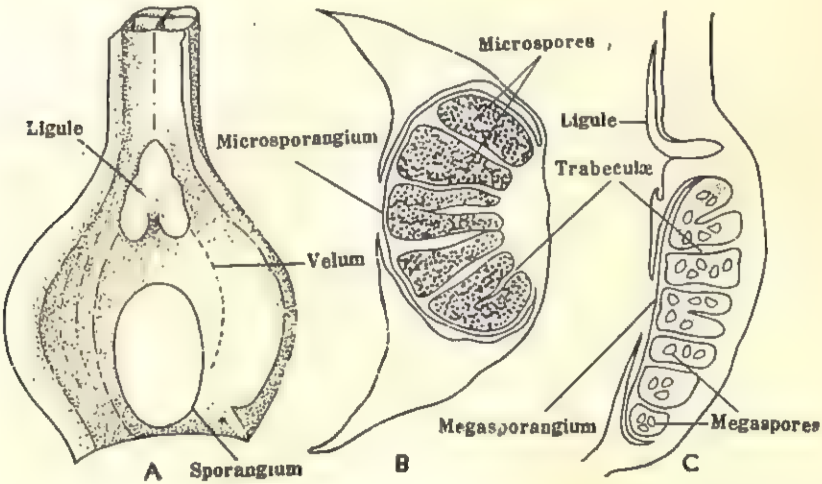


Fig. 331. *Isoetes.*
A, Basal portion of a leaf; B, Transverse section through the base of a microsporophyll; C, Longitudinal section through the base of a megasporophyll.

so-called rudimentary *antheridium*, consisting of an outer jacket layer of four cells and four inner spermatozoid mother-cells. Each spermatozoid mother-cell is ultimately metamorphozed into a large, spirally coiled, multiflagellate spermatozoid. The prothallial cell and the four jacket cells disintegrate and the spermatozoids are ultimately liberated by the decay of the spore-wall.

Female gametophyte. Each megaspore germinates and forms a female gametophyte and its mode of development resembles that of *Selaginella* with the following differences :

The germination starts with a series of free nuclear divisions and a conspicuous central vacuole is never formed in the protoplast (as in *Selaginella*) in any stage of development. The nuclei gradually become more numerous in the apical portion of the multinucleate gametophyte and an apical tissue is formed at this

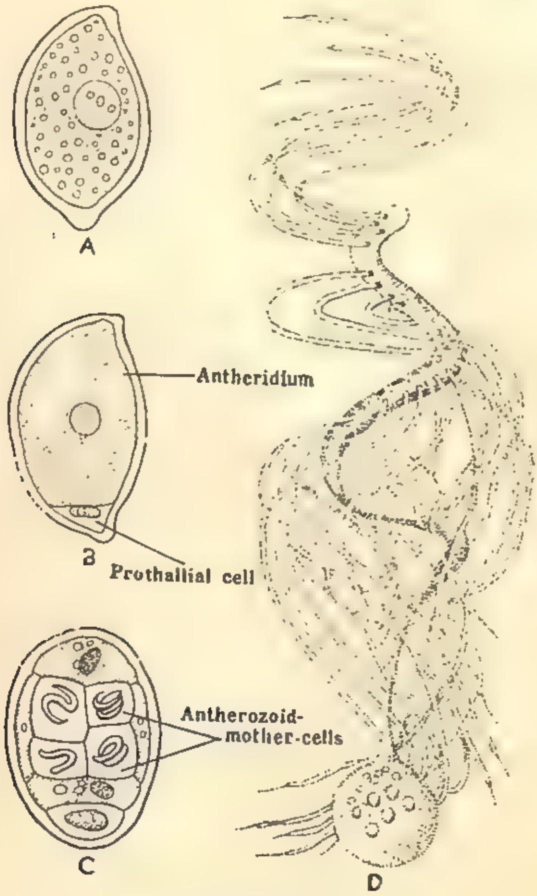


Fig. 332. *Isoetes.*
A—D, Stages in the development of antherozoid.

stage. The lower multinucleate portion of the gametophyte ultimately becomes cellular, but this process may be considerably delayed till the development of an adult embryo. The first-formed apical prothallial tissue is exposed by cracking of the spore-wall along the tri-radiate ridge and is devoid of chlorophyll. The

gametophyte does not protrude through the megaspore-wall, but may produce numerous rhizoids. The archegonium is broad and short, and consists of a single uninucleate neck canal cell, a ventral canal cell and an egg.

When the archegonium attains maturity the neck canal cell and the ventral canal cell disorganize. The multiflagellate spermatozoids swim towards the archegonium in dew or rain water, and one of them ultimately fertilizes the ovum. The fertilized ovum on secreting a wall round itself becomes an *oospore. With fertilization and formation of oospore, the sporophytic or diploid generation begins.*

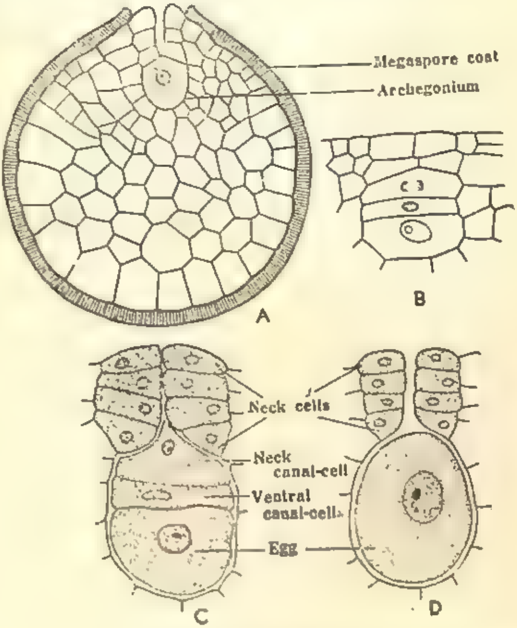


Fig. 333. *Isoetes.*
A, Longitudinal section of megaspore showing an archegonium; B—D, Stages in the development of archegonium.

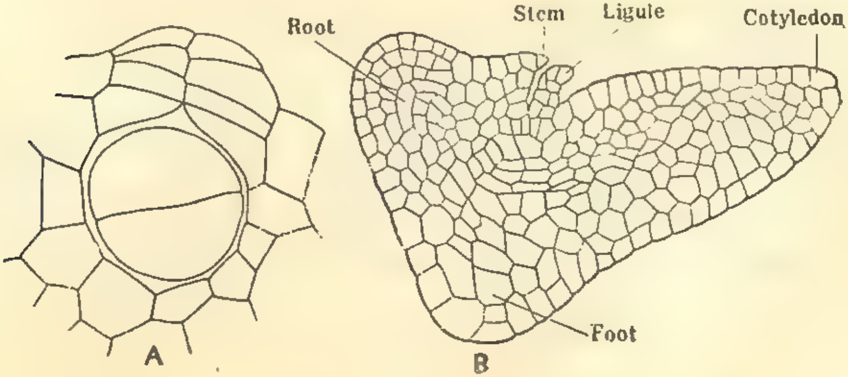


Fig. 334. *Isoetes.*
A, A developing embryo; B, Developing sporophyte.

The new sporophyte

The oospore gradually gives rise to an embryo possessing a massive foot, a root, the stem and a leaf (cotyledon) with a ligule. It is a peculiar feature that the embryo of *Isoetes* has no suspensor. Of the various parts of the embryo the stem appears to be a belated member. From this embryo the *Isoetes* plant is derived.

CLASS III. EQUISETINEAE

The members of the Class Equisetineae (also known as Articulatae) appeared in the Devonian, became very prominent in the Carboniferous and subsequently began to decline; at present the Class is represented by only one living genus *Equisetum*, the common 'horsetail'.

Sporophyte differentiated into stem, root and leaves; homosporous. Protostelic or siphonostelic; protoxylem endarch, but exarch in Sphenophyllales. Internodes longitudinally ribbed throughout. Branches and leaves alternating with each other at the nodes. Leaves generally borne in transverse whorls, and of two types—microphyllous (in Equisetales) and macrophyllous (in Sphenophyllales). Spores with elaters. Prothallus dorsiventral. Antheridia in *Equisetum* many and sunken. Sperms multiflagellate. Archegonia many, sunken, with two neck canal cells.

The Class consists of 5 Orders : (1) **Hyeniales,** (2) **Pseudoborniales,** (3) **Sphenophyllales,** (4) **Calamitales,** and (5) **Equisetales.**

ORDER 1. HYENIALES

Sporophyte usually with jointed stem. Whorled arrangement of leaves but not conspicuous. Leaves elongate, narrow, once or twice dichotomously branched, each with a terminal sporangium. Sporophores in lax strobili, without sterile appendages.

There are two genera : (*a*) **Hyenia,** and (*b*) **Calamophyton.**

HYENIA

(Fam. HYENIACEAE)

The genus *Hyenia* is known only from the Middle Devonian and

possesses some features which bring it nearer to the Psilophytineae than to the Equisetineae.

The plant is small and shrubby in nature, with short dichotomous appendages, a few of which are arranged in whorls. The aerial shoot is without any articulation and the internal structure is practically unknown. The appendages are of two types —sterile and fertile. The former are leafy and forked more than once. On the other hand, the latter ones have a single forking only with their tips either spreading or recurved. These fertile appendages are also borne in whorls and are equivalent to the sporangiophores, because at the end of each of the bifurcations at the distal end of a fertile appendage there are more than one anatropous sporangia.

Fig. 335. *Hyenia* (after reconstruction). (*Redrawn after Krausel and Weyland.*)

ORDER 3. SPHENOPHYLLALES

The Sphenophyllales first appeared in the Upper Devonian and persisted upto the Triassic. In all probability, the plants were herbaceous stem-climbers.

Sporophyte homosporous or incipiently heterosporous. Stem longitudinally ribbed. Primary vascular cylinder actinostelic,

tri- or hexa-arch; secondary tissues formed. Leaves arranged in whorls at the nodes, sessile, wedge-shaped, entire or dichotomously divided, with dichotomously branched veins. Sporangiophores and bracts densely crowded in alternate whorls in the strobili.

SPHENOPHYLLUM

(Fam. SPHENOPHYLLACEAE)

Sphenophyllum, the best studied genus of the Order Sphenophyllales, forms a characteristic vegetation of the coal-swamp forests of Scotland, France, Germany and Bear island in the Arctic ocean.

Fig. 336. *Sphenophyllum*. Plant body.

The sporophyte

On the nature of the habitats of the plant, it can be supposed that probably though the trailing stem of *Sphenophyllum* was mainly aerial in habit, yet under certain circumstances it might have been partially submerged under the swamp. The stems are slender, about 5 mm. in diameter, and are provided with non-alternating ribs. The leaves are small, usually less than 2 cm. in length, and occur in some multiple of 3 at each node, usually 6 or 9, but sometimes becoming as many as 18. The apex of the leaf is variously toothed; in some species (e.g., *S. myriophyllum*) the leaves are deeply notched. Each leaf possesses a number of diverging veins, produced from a single vein which undergoes several dichotomies.

Internally, the stem is rather confusing and appears to be like that of a root. The primary xylem occurs in the form of a triangle at the centre of the stem, thus making the stele an actinostele. The protoxylem is exarch. The primary phloem is not recognizable. The cortex is rather narrow and can be differentiated into an outer and an inner cortex. The whole of the cortex is used up in the formation of a periderm. In the intrastelar region the secondary xylem, derived from the cambium ring, is made up of tracheids with multiseriate bordered pits and parenchymatous ray cells.

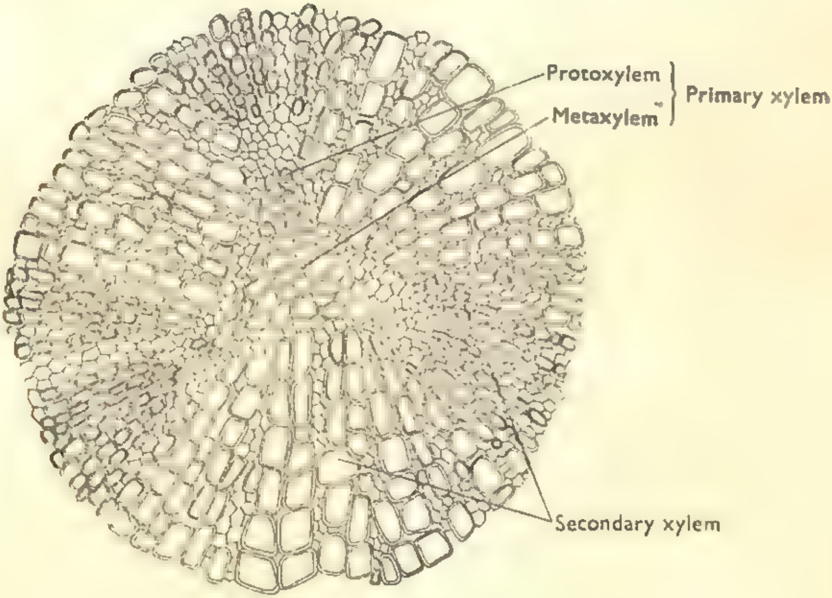


Fig. 337. *Sphenophyllum*.
T.S. of stem showing the xylem cylinder only.

Structurally, the internal organization of root is similar to that of the stem, excepting that the primary xylem is diarch instead of triarch*. The primary phloem is better preserved in the case of a root.

The strobili of *Sphenophyllum* are usually 1 cm. in diameter and with a variable length, and these are borne either terminally or laterally. The different types of sphenophyllean strobili are placed under the

* In very few cases it may be triarch also.

form genus *Bowmanites*, the best known species of which is *B. dawsoni*. In this case, there is a slender central axis bearing innumerable whorls of bracts at equal distances; each whorl is composed of 14-20 bracts, which are free at their apices but laterally united at the bases. In the axil of each bract there is a solitary **sporangiophore** partially united with the bract. The sporangiophores are of two kinds: (1) some having two short median arms and a long distal one,

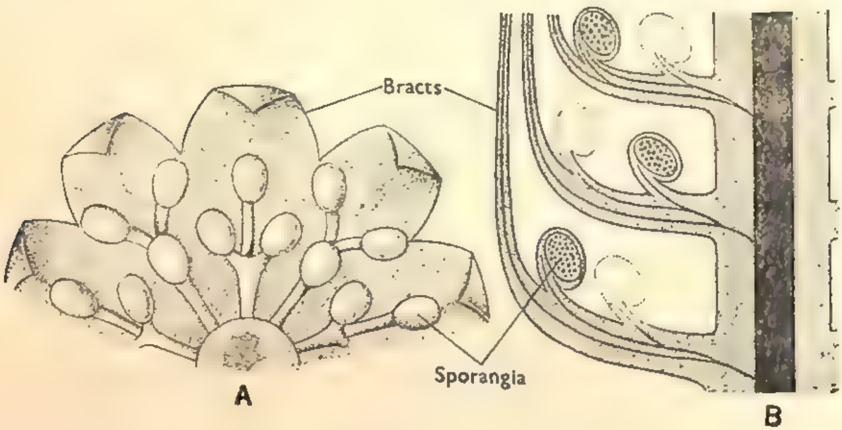


Fig. 338. *Sphenophyllum*.
A, T.S. of strobilus: B, V.S. of the same. (Diagrammatic).

and (2) some with two long distal arms and a single short median one. These sporangiophores alternate with one another in regular succession and each of their arms terminates in a single sporangium bearing mainly homospores.

ORDER 4. CALAMITALES

The members of the Calamitales constitute a diverse group of assemblage living in swampy habitats. The plants were both herbaceous and arborescent in habit representing the modern day equisetums. They appeared in the Upper Devonian, flourished luxuriantly forming one of the dominant elements of the Carboniferous flora, and finally declined in the Triassic.

Sporophytes mostly tall trees. Trunks usually unbranched, 20-30 metres high, and with a diameter of 1 metre ; siphonostelic. Secondary growth present. Leaves in one whorl at each node,

and in most cases small and simple, free or more or less united at the base. Sporangiophores and leaf-like bracts alternately arranged in the strobili. Homosporous or heterosporous. Megaspores usually three times larger than the microspores.

CALAMITES

(Fam. Calamitaceae)

The genus *Calamites* is very wide spread and can be found wherever Carboniferous plant-remains occur. The fossil remains, though quite common, are of a fragmentary nature and different parts of the plant are rarely found in an attached state. From the reconstructions, however, it appears that the main stems were large rhizomes bearing usually branched, ribbed, subaerial shoots, 20-30 metres high. The roots are adventitious. The leaves are simple, linear or linear-lanceolate and generally appear in whorls.

Internally, the stem of *Calamites* exactly represents that of *Equisetum*, excepting that in the former there is a clear secondary growth, both in the intrastelar as well as in the extrastelar regions. The secondary wood is very complex. The leaf-traces are also similar to those of *Equisetum*.

The strobili of *Calamites* consist of a number of sporangiophores bearing sporangia and resemble those of the present-day horsetails. Upto the present, four types of fructifications have

Fig. 339. *Calamites* sp. (after reconstruction). (*Redrawn after Hirmer*)

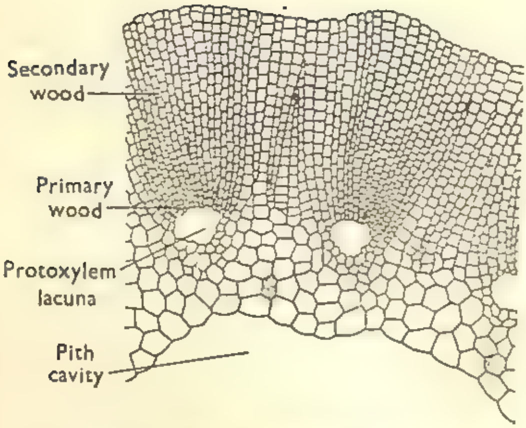


Fig. 340. *Calamites*. T.S. of stem in part).

been described, viz., *Calamostachys*, *Palaeostachya*, *Macrostachya*, and *Cingularia*. In case of *Calamostachys* the leafy bracts and sporangiophores are borne in alternate whorls on the axis, while in *Palaeostachya* the sporangiophores appear in the axils of the bracts. In *Macrostachya* the relation

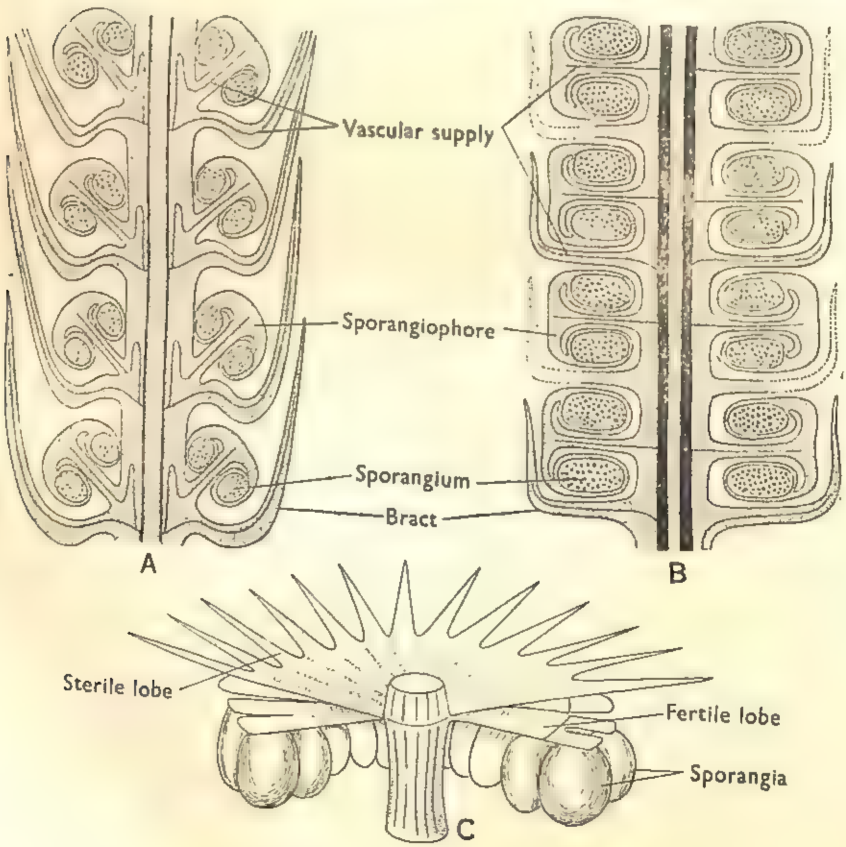


Fig. 341. *Calamites*.
A, V.S. of strobilus of *Palaeostachya*; B, Same of *Calamostachys*; C, A sporangiophore of *Cingularia* bearing sporangia.

between the bracts and the sporangiophores is probably of the *Calamostachys* type, the difference in between the two being in size, as the former is much bigger than the latter. In *Cingularia* the sporangiophore, which is horizontally placed, is divided into two lobes, an upper and a lower, the former one being usually a sterile bract. The lower lobe, on the other hand, is notched at its apex and each division bears two hanging sporangia. The sporangia normally have homospores, excepting in *Calamostachys casheana*.

ORDER 5. EQUISETALES

The Equisetales are characterized by having two kinds of shoots, subterranean rhizomes and branched, green, phylloclade-like subaerial branches provided with ridges and furrows; ribs of successive internodes usually alternating with one another. No secondary thickening; vascular cylinder siphonostelic, endarch. The leaves are scaly and are produced in whorls at the nodes. The strobili consist of peltate sporangiophores bearing a number of sporangia, hanging from their under surfaces. The spores, though morphologically homospores, are physiologically different.

The Order appeared in the Upper Devonian and reached its zenith in the Carboniferous, and is represented at present by the only genus *Equisetum* belonging to the family Equisetaceae.

EQUISETUM

(Fam. Equisetaceae)

Equisetum, commonly known as 'horsetail' is found with about 25 species all over the world excepting Australia and New Zealand, and is mostly an inhabitant of the cool and temperate regions. It is usually found in hills, especially in dark and marshy places, wet fields, gravelly or loamy soil.

The common Indian species of *Equisetum* are *E. diffusum*, *E. debile* and *E. robustum*.

The sporophyte

The plant is a herbaceous perennial one, but many are evergreen. The size of the plant is very variable, usually not exceeding a metre in length, but *E. giganteum*, a South American tropical species, grows to a height of about 10-20 metres.

The stem is a much-branched, dorsiventral, horizontal, rhizome which gives off many erect subaerial shoots, usually of two distinct types, **sterile** and **fertile.** The sterile shoots are green in colour,

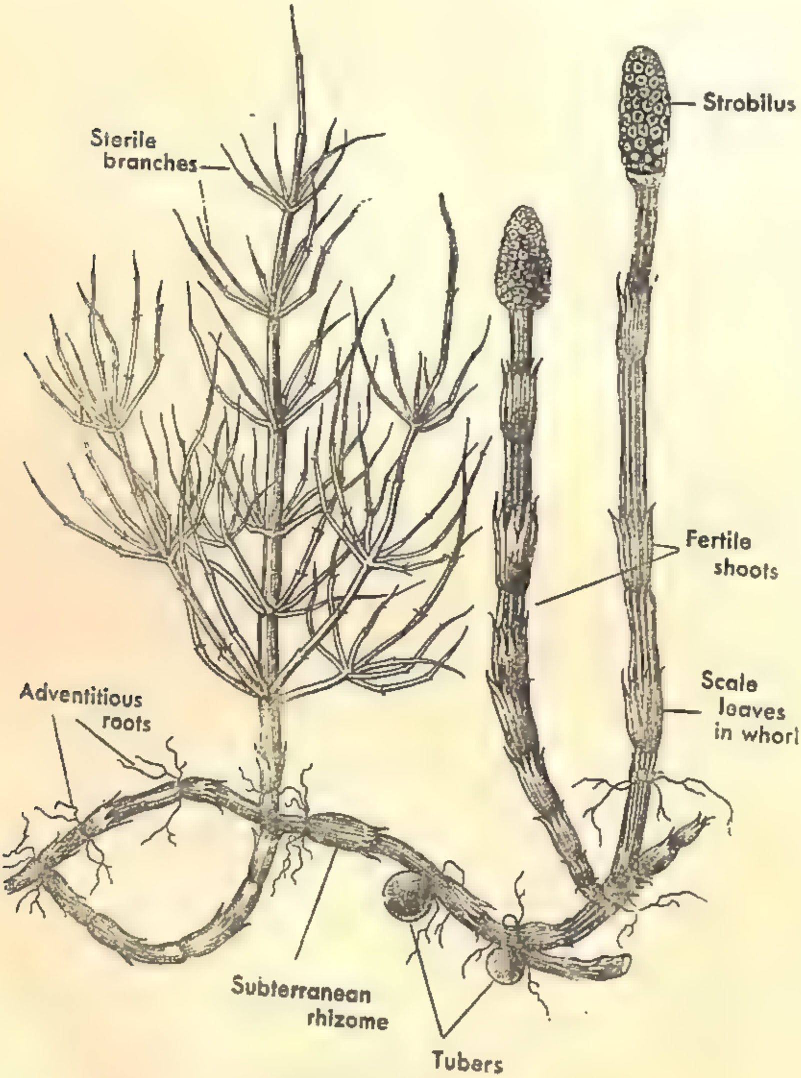


Fig. 342. *Equisetum.*
Sporophyte showing the horizontal rhizome with sterile and fertile shoots.

usually branched, perennial and vegetative in function. The fertile shoots are pale or brownish in colour, without chlorophyll,

unbranched, short-lived and wither after discharging their function (the production of spores). Transitional forms between these two types are not uncommon. The stem is jointed with nodes and internodes, and each internode consists of distinct ridges and furrows, the number of ridges is equal to the number of leaves present at each node. At each node there is a whorl of minute scale leaves, which are mostly non-green and soon become dead. These are free at the tips but fused laterally with one another forming a sheath closely enveloping the base of each internode. The function of

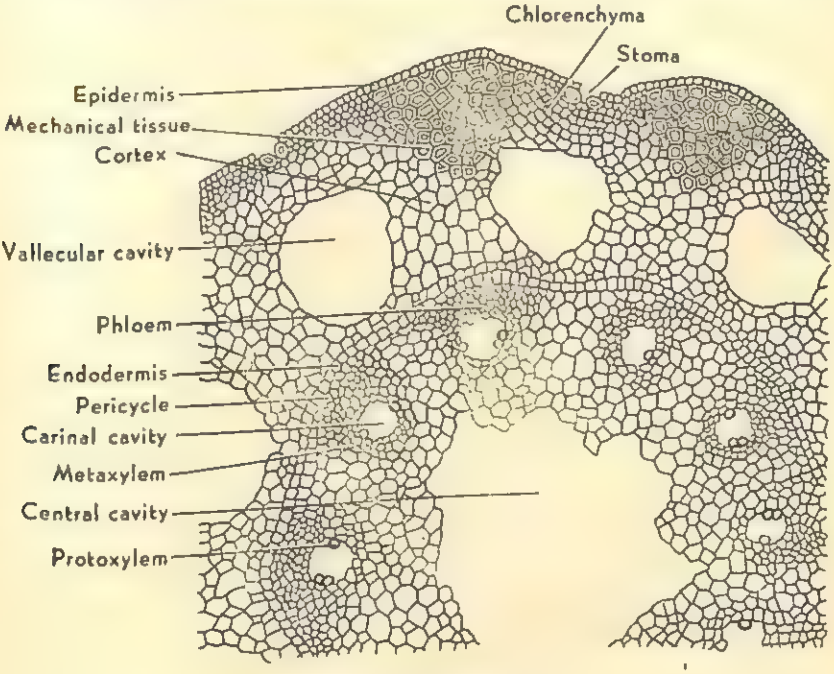


Fig. 343. *Equisetum*.
T.S. of stem (in part).

photosynthesis is, however, taken by the stem and branches. The branches are in whorls and usually equal in number to the leaves, a branch always developing between a pair of leaves. The whorls of leaves and branches of successive nodes alternate with one another.

Roots are slender, fibrous, adventitious in nature and arise endogenously from the bases of the lateral branches or dormant buds of the rhizome.

A cross section of the stem shows two regions clearly differentiated, the cortex and the stele. The cortex is bounded on the outside by an epidermis which is single-layered and provided with a number of alternate ridges and furrows. The outer walls of the epidermal cells are highly silicified. Stomata are present in two vertical rows in each furrow. The cortex is highly differentiated into the following: (*a*) hypodermis consisting of sclerenchyma which may be restricted to the periphery of the cortex or may extend inwards to the stele; below each ridge sclerenchyma is well-developed, (*b*) general cortex consisting of many-layered parenchyma with large air cavities (**vallecular cavities**), each corresponding to a furrow, and

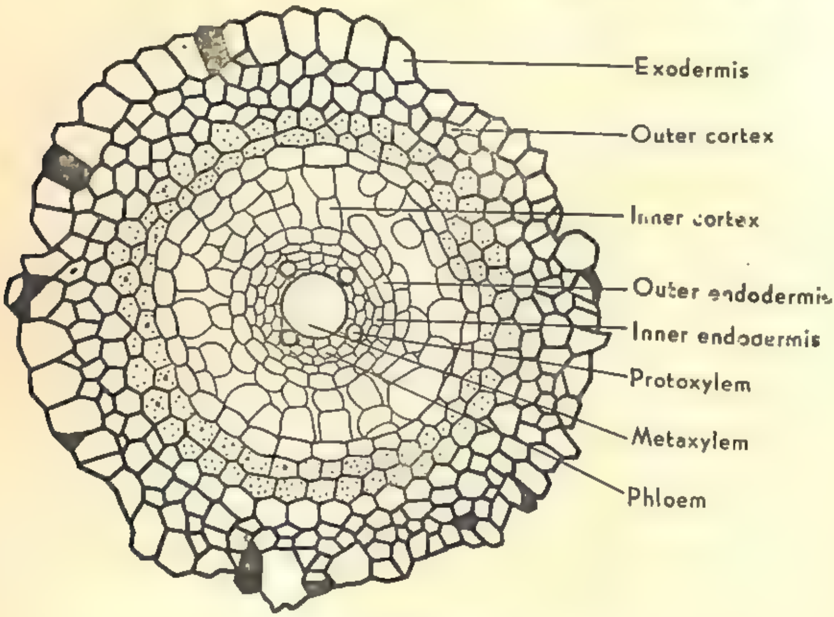


Fig. 344. *Equisetum.*
T.S. of root.

these alternate in position with usually water-filled cavities (**carinal cavities**) in the vascular bundles. The peripheral portion of the general cortex, lateral to the sclerenchyma, is chlorenchymatous with intercellular spaces and especially conspicuous just beneath the stomata, and (*c*) endodermis surrounding the entire stele with prominent casparian strips. In some species, each vascular bundle is surrounded by an individual endodermal layer. Lying internal to the endodermis there is the pericycle consisting of a single layer

of parenchyma cells. The vascular bundles are closed, collateral, and conjoint being arranged in a ring and each containing a carinal cavity; they are laterally separated from one another by a small mass of parenchyma cells. The protoxylem is endarch and in mature bundles these are found in a more or less disorganized condition within the carinal cavities. Outside the carinal cavity is a mass of phloem consisting of phloem parenchyma and sieve-tubes. On both sides of the phloem mass is a small metaxylem mass consisting of tracheids only. The pith lies at the centre. Occupying most of the pith there is a conspicuous space (the **central cavity**) in the internodes of the primary branches of the aerial shoots, and this central cavity may be entirely absent in the internodes of smaller branches and of the rhizome ; these cavities also are usually water-filled.

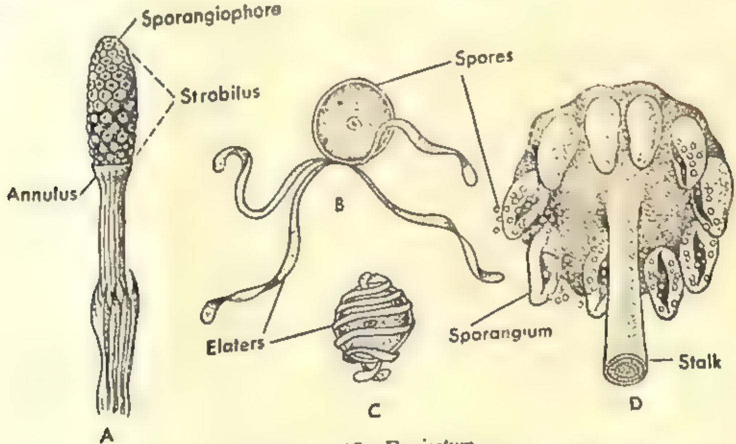


Fig. 345. *Equisetum*.
A, A portion of the fertile shoot bearing a terminal strobilus; B & C, Spores with elaters; D, A sporangiophore with sporangia on its under surface.

Internally, the root of *Equisetum* possesses an exodermis followed by a thick cortex. There are two endodermal layers,—the outer endodermis and the inner endodermis, which replaces the pericycle. There are usually four protoxylem groups alternating with the phloem and a big central metaxylem.

At the apex of the fertile branch there is a cone-like structure, the **sporangiferous spike** or **cone** or **strobilus,** which consists of a central axis bearing a variable number of sporangium-bearing organs, the **sporangiophores,** in distinct but compact whorls. Each sporangiophore is a peltate structure with a somewhat flattened

hexagonal disc and is attached to the main axis at right angles to each other. When young, these sporangiophores remain closely-fitted together, but later on separate as distinct whorls. At the base of the strobilus, in some cases, a modified leaf-whorl is present forming the so-called **annulus.**

On the under surface of each sporangiophore, towards the circumference, sporangia, usually 5-10 in number, are borne on a

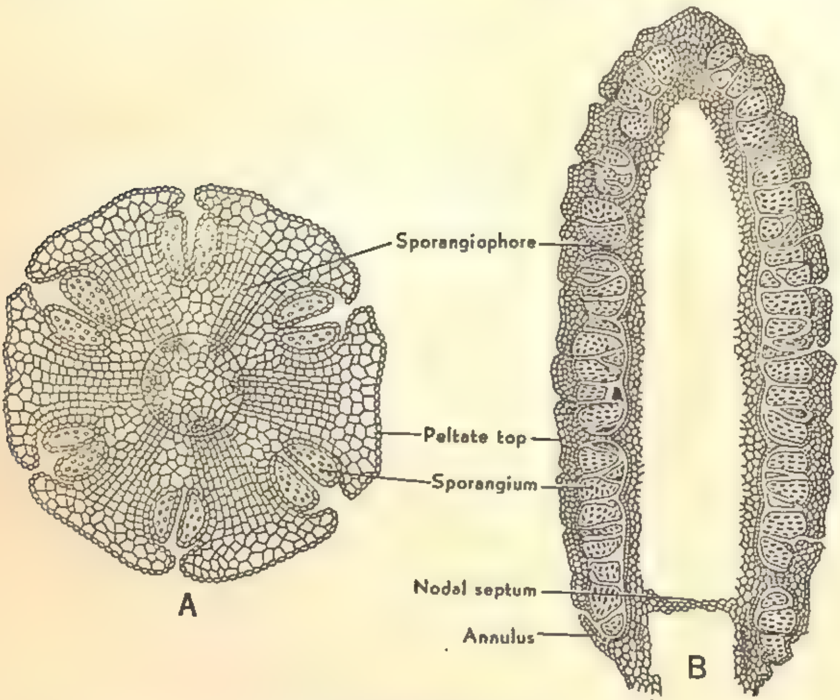


Fig. 346. *Equisetum.*
A, T.S. of a strobilus; B, L.S. of the same.

ring and are projected horizontally towards the axis of the cone. Each sporangium is an elongated, sac-like body containing many spore mother-cells, from each of which four spores are formed due to reduction division, so that a mature sporangium contains many spores inside. *With reduction division and formation of spores, the gametophytic or haploid generation begins.*

The gametophytes

The sporangium, at maturity, bursts longitudinally and sets free a large number of green-coloured spores. Each spore, besides

its usual two coats, has a delicate cuticular layer and a thick **perispore.** Later on, this last layer splits into four ribbon-like appendages, called **elaters,** with spoon-like tips and these remain attached to a common point. These elaters are hygroscopic in nature, which uncoil in dry air and recoil around the spore in moisture. The function of the elaters is uncertain. Possibly, their expansion may

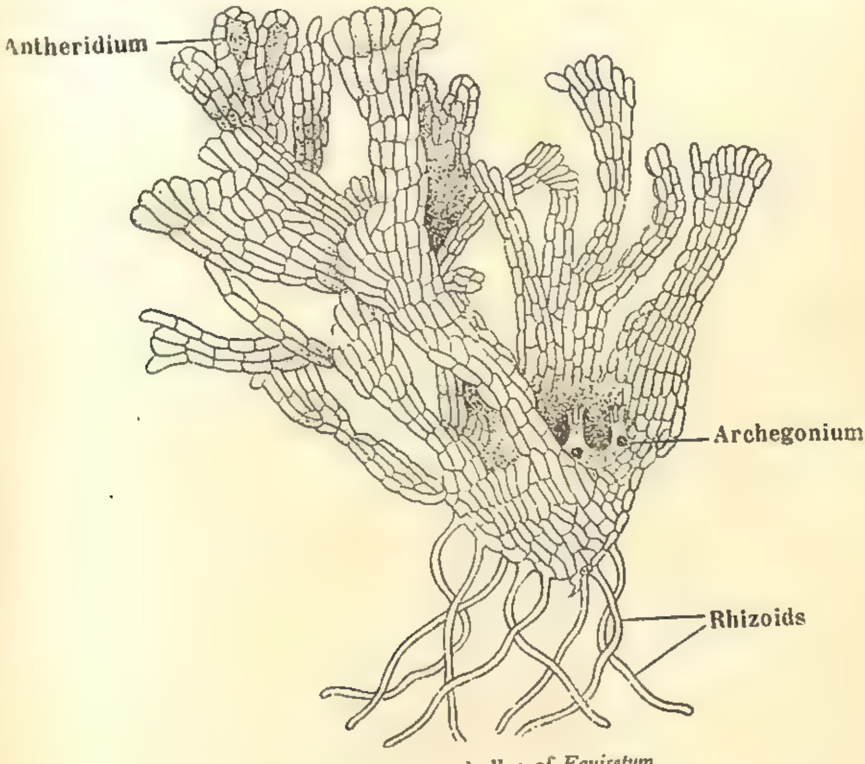


Fig. 347. Monoecious prothallus of *Equisetum*.

assist in the dehiscence of the sporangia, or possibly their expansion and contraction may assist in spore-dispersal. The spores are all of one kind. Hence, *Equisetum* is homosporous.

On germination, each spore forms a small green prothallus which differs in form and in the position of sex organs (*antheridia* and *archegonia*) from that of a fern. At maturity, it looks like a disc-shaped thick cushion of tissue consisting of several layers of cells, from the upper surface of which there arise irregularly-lobed flattened branches, each one cell in thickness. It produces rhizoids from its lower surface. Antheridia usually develop at the upper

ends of these flattened and vertical branches, while the archegonia are produced on the upper surface of cushion near the bases of these branches. Thus, the prothallus is monoecious. On the other hand if the gametophytes remain small, each one-cell in thickness, probably due to nutritional deficiency, they bear antheridia only and it is for these reasons they were once thought to be dioecious. In some cases (*E. arvense*), half of the spores develop male

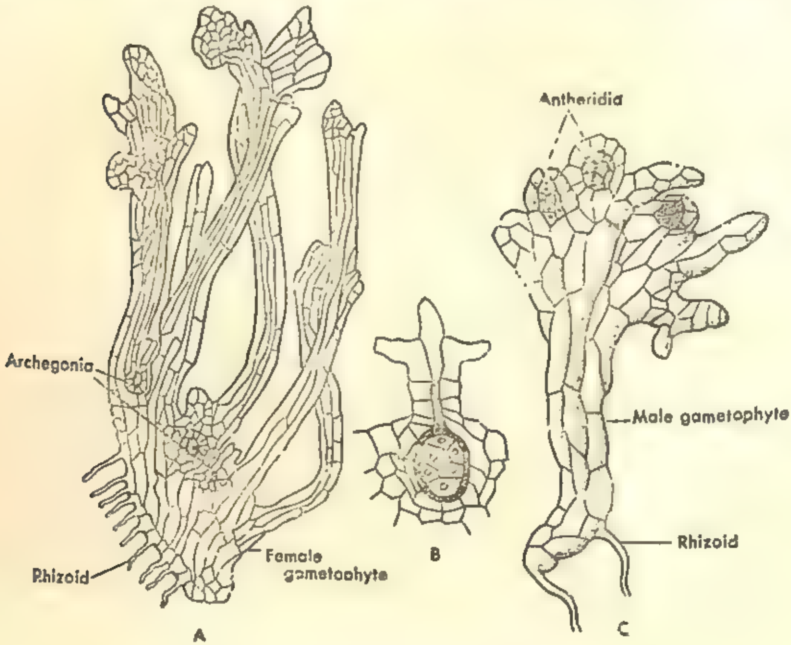


Fig. 348. *Equisetum arvense.*
A, A female prothallus; B, An archegonium;
C, A male prothallus.

gametophytes and the other half, female gametophytes under controlled conditions. In the latter case, if fertilization of the archegonia fails prothallia proceed to develop antheridia. The prothallia may be long-lived and may persist for more than two years.

Each antheridium consists of an outer jacket layer, one cell in thickness, surrounding a number of spermatozoid mother-cells (**spermatocytes**), each of which is ultimately metamorphozed into a spirally-coiled *antherozoid* with numerous flagella.

The archegonium consists of a *neck* (3 or 4 cells in height) and a *central cell* projecting vertically above the prothallus. The central

cell divides transversely into a *primary canal cell* and a *primary ventral cell*. The primary canal cell vertically divides into two *neck canal cells*, while the ventral cell asymmetrically divides into a *ventral canal cell* and an *egg*. At maturity the canal cells disintegrate and the egg is ready for fertilization.

Fertilization is effected by antherozoids, which swim down the canal of the archegonium and only one fuses with the egg. The fertilized egg then surrounds itself with a wall and forms an **oospore.** *With fertilization and formation of oospore, the sporophytic or diploid generation begins.*

Fig. 349. An antherozoid of *Equisetum*.

The new sporophyte

The oospore passes into an embryo (consisting of stem, root, cotyledon, and foot) which, without any period of rest, continues to grow until the *Equisetum* plant is established and thus completes the life cycle. It has been observed in the case of *E. debile* that a single gametophyte may bear eight to ten young sporophytes.

CLASS IV. FILICINEAE

The Class Filicineae is a comparatively larger group than other Classes of Pteridophytes and contains about 175 genera with 8,000 species. The members are very varied in their habit and habitat. Some of the genera are cosmopolitan in their distribution, while others are strictly endemic. The earliest members of Filicineae appeared in the Devonian but it is believed that the ancestors of the present-day ferns evolved during the Triassic and Jurassic.

As the Ferns include a very heterogeneous assemblage of plants, for the sake of convenience all the fossil members of the group are placed in a single Subclass I. **Primofilices** (e.g., *Archaeopteris*), while the living ones are grouped under two distinct subclasses—Subclass II. **Eusporangiatae** and Subclass III. **Leptosporangiatae.***

The Eusporangiate ferns include *two* Orders: (1) **Ophioglos-**

* Prof. A. J. Eames, however, recognizes three major groups: (1) **Ophioglossales,** (2) **Marattialles,** and (3) **Filicales** under the Filicineae.

sales (e.g., *Ophioglossum*, *Botrychium*, and *Helminthostachys*), and (2) **Marattiales** (e.g., *Marattia*, *Angiopteris*, *Danaea*, etc.). The Leptosporangiate ferns, on the other hand, comprise of *three* Orders: (3) **Filicales** (e.g., *Polypodium*, *Pteris*, *Asplenium*, *Aspidium*, *Osmunda*, *Hymenophyllum*, *Gleichenia*, *Cyathea*, etc.), (4) **Marsileales** (e.g., *Marsilea*), and (5) **Salviniales** (e.g., *Salvinia*, *Azolla*).*

SUBCLASS I. PRIMOFILICES

ARCHAEOPTERIS

(Fam. ARCHAEOPTERIDACEAE)

Archaeopteris is one of the most ancient ferns, known only from the Devonian and that also from the Upper Devonian. The genus is based on leaf compressions. Recently, the leaves have been found attached to the *Callixylon* type of stem (a gymnosperm). The leaves are large and possess a rachis bearing almost opposite pairs of pinnae and a pair of stipules at the base of the rachis. A pinna, in its turn, bears a number of pinnules which are arranged in an alternate fashion. The pinnules on a pinna may be either all sterile or all fertile, or there may be an admixture of the two. The sterile pinnules are flat and oval or wedge-shaped with repeatedly dichotomous venation, which extend upto the entire or incised apices.

Fig. 350. *Archaeopteris*.
A, Pinna with fertile and sterile pinnules; B, Reconstruction of a portion of fertile pinnule with sporangia; C, Microspore; D, Megaspore.
(*Redrawn after Schimper and Arnold*)

The sporangia are borne in a psilophyte-like fashion on the tips of branched or unbranched pedicels, which are

* Some authorities include the last two Orders under the name **Hydropteridales** (*i.e.*, water ferns).

borne adaxially on a fertile pinnule. The spores in one species can be differentiated into micro- or mega-spores and both kinds of sporangia are situated on the same pinnule. In size, the megaspores are about ten times in diameter than the microspores. It is interesting to note, however, that both the micro- and mega-sporangia are approximately of the same length, but the latter are about double the former in breadth. A single microsporangium contains more than one hundred microspores, while a megasporangium contains only eight or sixteen megaspores.

SUBCLASS II. EUSPORANGIATAE

ORDER 1. OPHIOGLOSSALES

The Order Ophioglossales includes a single family *Ophioglossaceae*, popularly known as "Adder's tongue ferns". It consists of three living genera only, of which *Ophioglossum* and *Botrychium* are cosmopolitan in their distribution, while the monotypic genus *Helminthostachys* is endemic to the Indo-Malayan region. This Order is regarded as a very primitive one.

OPHIOGLOSSUM

(Fam. Ophioglossaceae)

The genus comprises of 28 species. The common Indian species are *O. gramineum*, *O. vulgatum*, *O. nudicante*, *O. reticulatum*, etc.

The plant is characterized usually by the presence of a short, erect, rhizome, which rarely undergoes a dichtomous branching. Many adventitious roots are borne on the underground stem. In the majority of species there is only one leaf produced by the plant every year. Each leaf is clearly differentiable into a petiole and a lamina, the venation being of the reticulate type. The leaves may be simple or lobed and sometimes fork in a dichotomous manner; the phyllotaxy is spiral. The circinate type of ptyxis is unknown in this case.

Internally, the stem is siphonostelic as a rule, but occasionally the basal region of the stem may be protostelic with the upper part siphonostelic. The xylem is endarch with phloem lying external to xylem. The pith is generally homogeneous and composed of comparatively large, thin-walled, parenchyma cells, but in some

cases (e.g., *O. pendulum*) small scattered patches of xylem may be found in the pith. In *O. vulgatum* a small amount of secondary growth has been noted.

The cortex of the root is a massive structure whose innermost layer gives rise to a typical endodermis. The outer region of the cortex is made up of angular parenchyma cells without any intercellular space and harbours a phycomycetous mycorrhizal fungus. The inner region is composed of more or less rounded cells with prominent intercellular spaces. The stele may be monarch to tetrarch with radially arranged xylem and phloem; xylem is exarch.

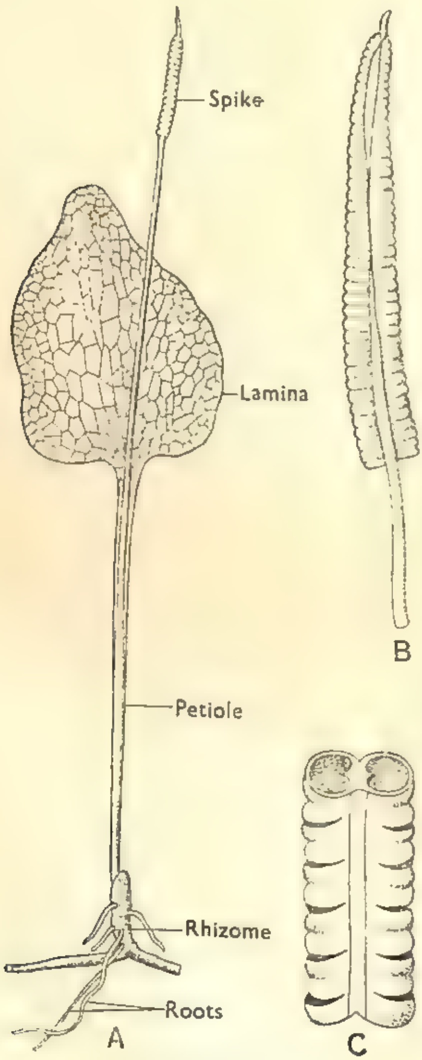


Fig. 351. *Ophioglossum.*
A, An entire plant; B, A mature spike; C, T.S. through the apical portion of B.

All the species of *Ophioglossum*, excepting *O. palmatum*, bear a single, linear, simple or slightly irregularly branched **fertile spike** at the junction of petiole and lamina. This spike resembles the tongue of an adder. There is a good deal of controversy regarding the morphological nature of the fertile spike in *Ophioglossum* (see below). The sporangia, however, are 0·5-3·0 mm. in diameter, sub-spherical and sunken within the leaf-tissue; these are also regarded by some to be fused forming a **synangium** along the

margin of the leaf. There are two marginal rows of sporangia which are eusporangiate in their mode of development. *With reduction division and formation of spores, the gametophytic or haploid generations begins.* At maturity, the sporangia turn yellowish or brownish in colour and dehisce by means of a 'lateral' slit, liberating the spores in multitude. The spores are originally tetrahedral but later on become sub-spherical; the wall is thick and sculptured.

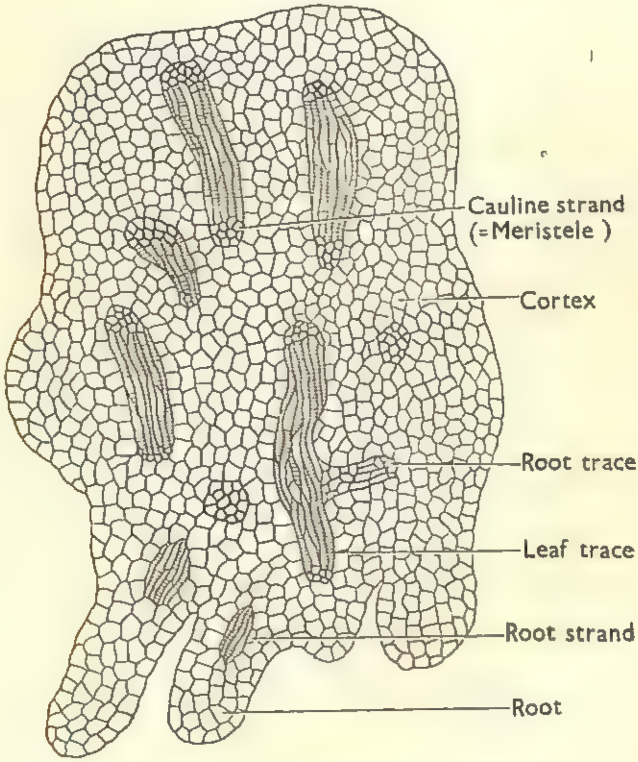


Fig. 352. *Ophioglossum reticulatum.*
T.S. of rhizome with adventitious roots.

Morphology of the spike. Speculation on the morphological nature of the fertile spike of Ophioglossaceae dates at least from the time of Roeper (1826, 1859), who suggested that the spike in *Botrychium* has been derived from two basal pinnae of the sterile frond, and is secondarily erected upright, as in case of *Anemia.* It was later shown by Holle (1875) that Roeper's theory might be

applied to *Ophioglossum*. Bower (1896), however, considered the spike of *Ophioglossum* as a septate sporangium, but this hypothesis was rejected by himself in 1911. Chrysler (1910) supported Roeper's view. He found that the fertile spike of *Botrychium* has the same number of vascular supply as would naturally go to a pair of pinnae. He further pointed out that in the abnormal specimens, where there is a pair of fertile spikes instead of one, each spike has the same number of vascular supply as would be present in a single pinna. The pinna-nature of the fertile spike is more

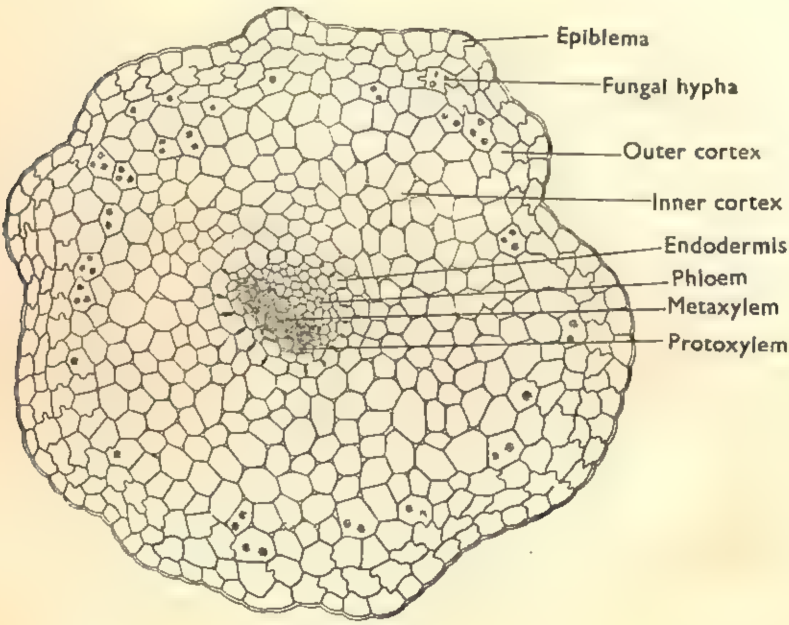


Fig. 353. *Ophioglossum*.
T.S. of root.

evident in *Botrychium lanuginosum*, where the spike is situated in the middle of the lamina, and in the position of the third to the sixth leaflets from the base. However, the strongest evidence against the pinna-nature of the fertile spikes is found in *Ophioglossum palmatum* (Bower, 1911; Sen, 1961). In this species, unlike the pinnae, at least some of the spikes are non-marginal in position.

Recently the frond has been re-interpreted by Chrysler (1945), Nishida (1957), Sen (1961) and others in the light of branching of its

vascular tissue. The repeated dichotomous branchings of the vascular tissue are considered as being indicative of a once-free dichotomous branch system characteristic of Coenopteridales, and the fronds of Ophioglossales are thus considered as intermediate forms, connecting the archaic radial types with the modern plane fronds.

Some species of *Ophioglossum* (*O. vulgatum*) can reproduce vegetatively by means of root buds.

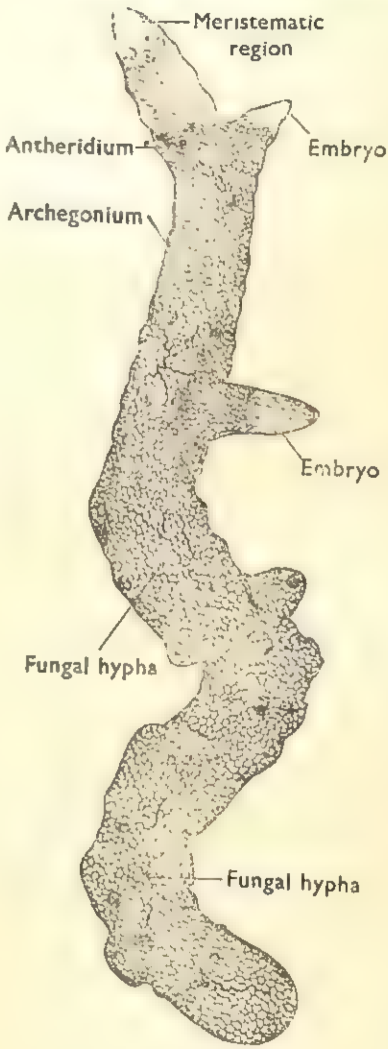


Fig. 354. *Ophioglossum*. A mature gametophyte.

The gametophyte

A spore on germination, sooner or later, gives rise to a **prothallus,** which in its early stage of development becomes infected with an endophytic mycorrhizal fungus. In case of entirely subterranean prothalli, this fungus is responsible for the supply of food to the young gametophyte. In some cases, however, the prothalli possess small, subaerial green lobes. A mature prothallus of *Ophioglossum* is conical or irregularly cylindrical or stellate, a few mm. long, unbranched or copiously branched and perennial in habit. The sex organs are scattered generally near the growing tip of the prothallus and are formed in an irregular sequence, but in acropetal succession.

An antheridium develops from a superficial cell (**antheridium initial cell**) of the prothallus, which divides periclinally into an outer and an inner cell. This inner cell gives rise to the

antheridium proper. The antherozoids are coiled and multiflagellate.

An archegonium is also developed from a single superficial cell of the gametophyte. Here also, the first division of the **archegonial initial cell** is periclinal. The neck of the archegonium is slightly

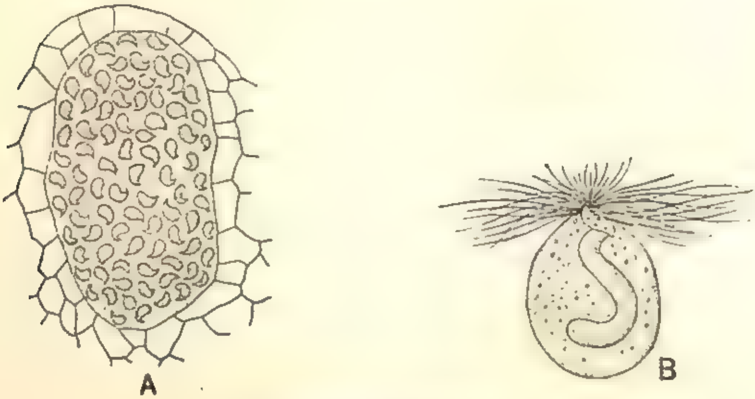


Fig. 355. *Ophioglossum.*
A, A mature antheridium; B, A single antherozoid.

projecting beyond the surface of the prothallus. The ventral canal cell is extremely transitory in nature. By disintegration of the canal cell or canal cells an opening is formed in the neck of the archegonium, through which an antherozoid glides in and fuses with the egg cell, thereby causing fertilization. The fertilized egg soon covers itself by a wall and forms the **oospore.** *With fertilization and formation of oospore, the sporophytic or diploid generation begins.*

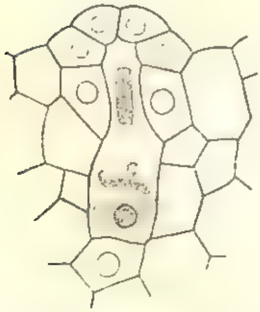


Fig. 356. *Ophioglossum.*
A mature archegonium.

The new sporophyte

The new sporophyte develops from the oospore in course of a year, or the development may take place through a number of years. In all the species investigated so far, the first division of the oospore is approximately transverse, producing an upper cell, the **epibasal cell,** and a lower one, the **hypobasal cell.** It cannot be said with certainty whether the latter one

gives rise to the foot only, or to the foot as well as the primary root. The epibasal cell develops into the stem and the first leaf.

Fig. 357. *Ophioglossum.*
Diagrammatic representation of a developing embryo.

SUBCLASS III. LEPTOSPORANGIATAE

ORDER 3. FILICALES

The members of the Filicales or 'true ferns' are worldwide in their distribution. Like the eusporangiate ones, they also inhabit warm, moist and shady places, and the majority of them are mesophytes or hydrophytes, although xerophytic types are by no means uncommon. These are usually perennial plants. The Order is characterized by homospory. The sorus may be **simple** (all sporangia developing simultaneously), **gradate** (sporangia developing in a basepetal succession), or **mixed** (sporangia developing in an irregular sequence).

There are a number of Families included under the Order with about 300 genera and 9,000 species (Copeland, 1947).

Geological records show that the members of this Order are comparatively younger than other groups of ferns and date back from the Permian and in all probability reached their climax in the Lower Cretaceous.

POLYPODIUM

(Fam. POLYPODIACEAE)

Polypodium is commonly found in tropical and temperate regions growing in the woods, hedge rows and near streams. Though it prefers shady places, it is somtimes found in more exposed situations, such as hill sides.

The genus comprises of 75 species. The common Indian species are *P. parasiticum*, *P. cucullatum*, *P. decorum* and *P. obliquatum*.

The sporophyte

The stem of *Polypodium* is a perennial, sparingly branched, erect or creeping rhizome, which when destitute of **fronds** (leaves) has the appearance of some kind of sea polypus. Usually, the greater part of the rhizome is subterranean, but it grows obliquely upwards and its apex rises a little above the surface of the ground and bears the leaves. This erect or ascending region is known as the **caudex,** often clothed with dense growth of scales, epidermal hairs or adventitious roots. The older portion of the stem shows the presence of persistent leaf-bases of the dead fronds, and when this portion dies the branches become disconnected and continue to develop as separate new plants.

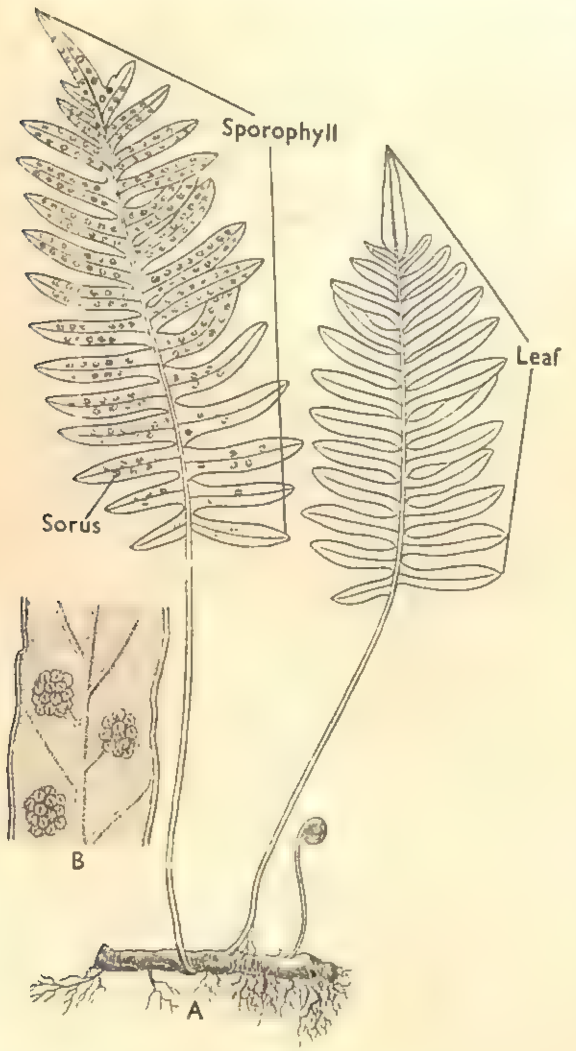


Fig. 358. *Polypodium*.
A, An entire plant;
B, Portion of pinna with three sori.

The primary root dies early, all

subsequent roots are adventitious and arise from lower side of the rhizome. Each root has a root cap and root hairs.

The leaves, often called **fronds,** are either simple, entire or pinnatifid or pinnately compound, and when young show characteristic **circinate ptyxis.** Annually, rosette of leaves unfold from the caudex portion of the rhizome and these ultimately die at the close of the growing season. The petioles (**stipes**) are short or slightly longer, tufted and are often clothed with numerous brown hairs known as **ramenta,** which are characteristic of ferns. These hairs are also present on the rachis. The veins of the leaf-segments are either simple or forked and ultimately bear groups (**sori**) of asexual reproductive organs (**sporangia**) and are, therefore, soriferous.

A cross section of the rhizome shows two distinct regions, the cortex and a number of steles. The cortex is bounded on the outside by an epidermis consisting of a single layer of narrow cells with thick

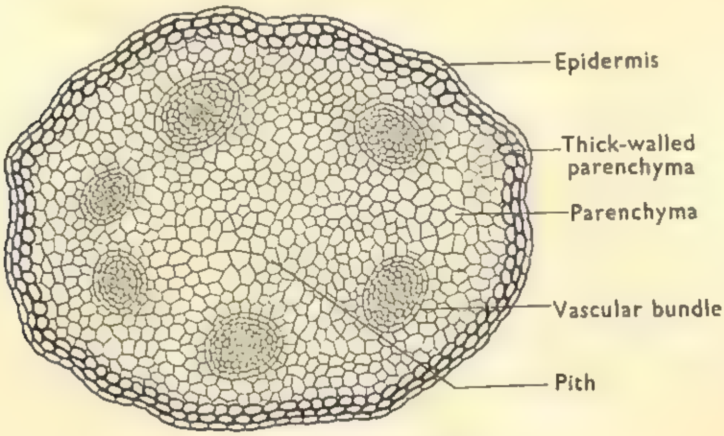


Fig. 359. *Polypodium.*
Transverse section of rhizome.

walls. The cortex is differentiated into two regions: (*a*) hypodermis consisting of a few layers of thick-walled parenchyma, (*b*) general cortex consisting of many layers of parenchyma cells with or without intercellular spaces; this tissue is mainly concerned with the storage of food and water. The vascular bundles vary in number, some of which are large and others are small and are generally found near about the centre of the stem. Each vascular bundle is discrete and hadrocentric and is surrounded by a typical endodermis,

lying internal to which there is a single layer of pericycle; the protoxylem is exarch. The phloem consists of sieve-tubes and 'conjunctive' parenchyma, and the xylem consists of tracheids varying in width with thick lignified walls and 'conjunctive' parenchyma like that of phloem. There is pith in the centre of the rhizome. Leaf-trace bundles are present in the cortex.

Early in summer, the foliage leaves bear on their under surface many greenish brown structures, called **sori,** which are developed directly over the veins so that the foliage leaves are now spoken of as **sporophylls.** Thus, in *Polypodium*, there is no differentiation into

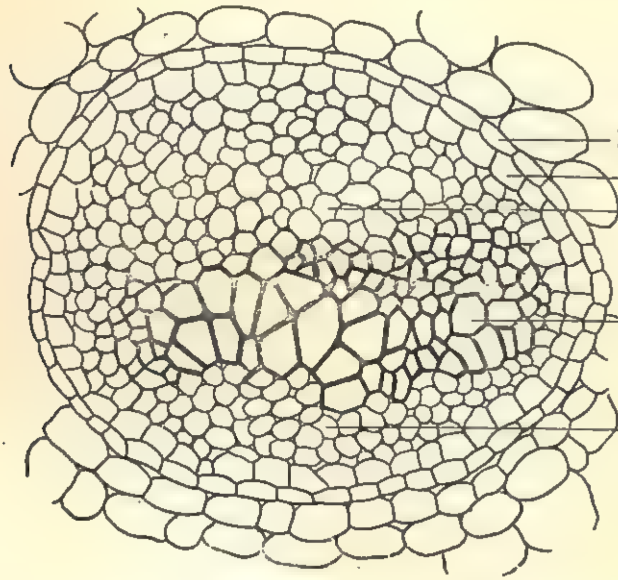


Fig. 360. *Polypodium.*
A stele (much enlarged).

foliage leaves and sporophylls, both the functions of photosynthesis and spore-production are taken over by all the leaves. The sori are generally round, large or small, and sometimes are mixed with hairs. They are generally terminal on the veinlets or at their bases forming a regular row on each side. Each sorus is naked and consists of a group of sporangia which arise from a tissue of the leaf, called **placenta***. Each sporangium develops by the *leptosporangiate*

* In some other genera of ferns it is protected by an **indusium,** outgrowth from the placenta.

*method.** The fully-formed sporangium is a lenticular **capsule** attached to the stalk. On the capsule there is a specialized,

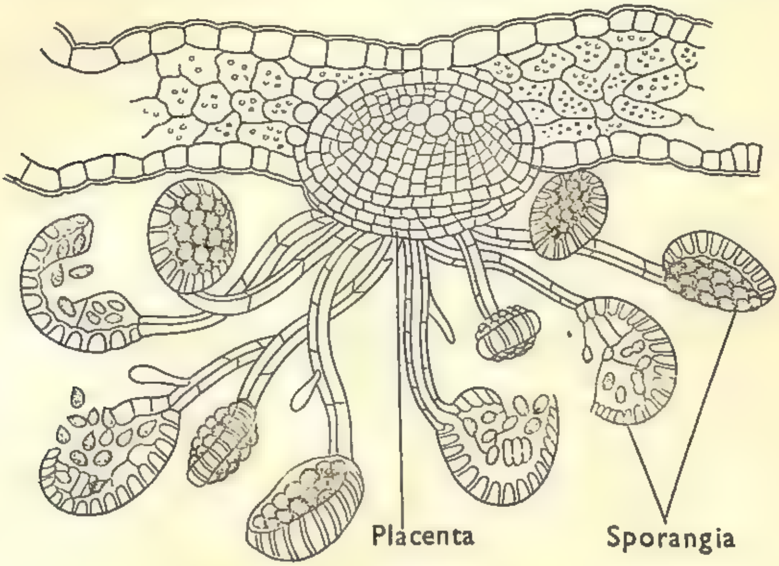


Fig. 361. *Polypodium.*
T.S. of leaf through a sorus.

cutinized, incomplete cellular layer called **annulus.** Where the annulus stops short, the cells are thin and form what is called **stomium.** Within the single-layered wall of each sporangium there are one or two layers of nutritive tissue, the **tapetum,** surrounding a mass of sporogenous cells, which ultimately form about sixteen spore mother-cells. From each cell, by reduction division, a spore-tetrad is formed. When mature, the spores are dark brown in colour and morphologically alike,—hence *Polypodium* is homosporous. *With reduction division and formation of spores, the gametophytic or haploid generation begins.*

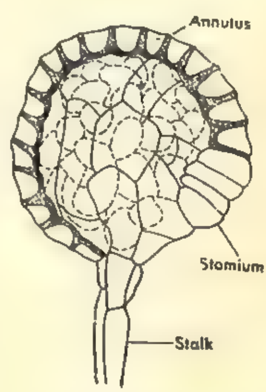


Fig. 362. *Polypodium.*
A sporangium.

* It means that the development of the sporogenous tissue takes place from the *outer* cell following the periclinal division of the superficial initial instead of from the *inner* cell, as in *Lycopodium.*

The gametophyte

When the sporangium ripens, it bursts at the stomium owing to the hygroscopic movement of the annulus and the spores escape. Each spore has two coats: the outer coat is called **exospore** and the inner coat, **endospore.** Under proper conditions of temperature

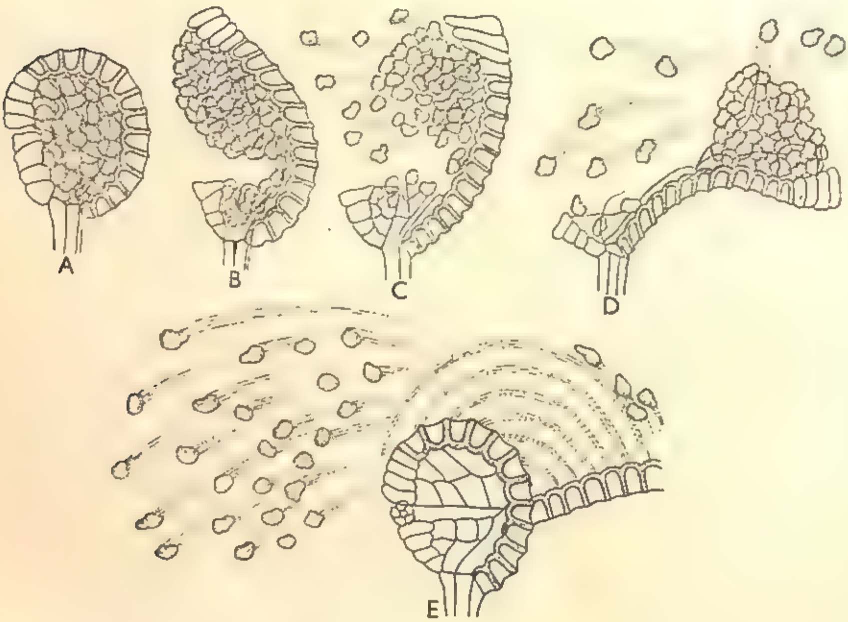


Fig. 363. *Polypodium*.
A—E, Successive stages in the dispersal of spores from sporangium (*after Atkinson*).

and moisture each spore germinates. On germination, the outer coat bursts and the inner one elongates and protrudes into a multicellular filamentous structure, which when fully developed forms a flat, green, heart-shaped body called **prothallus.** The prothallus gives out from its under surface many delicate, unicellular, hair-like structures called **rhizoids,** by means of which the prothallus is not only attached to the substratum but it also draws nourishment therefrom. The prothallus is, therefore, an independent plant which can absorb raw food materials from the substratum and can carry on photosynthesis. The prothallus bears on its under surface, scattered among the rhizoids, especially on the thicker part of it, several multicellular bodies of two distinct kinds:

(1) **antheridia** or the male sex organs, and (2) **archegonia** or the female sex organs.

Each antheridium is a spherical body and contains about thirty-two spermatozoid mother-cells (**spermatocytes**), from each

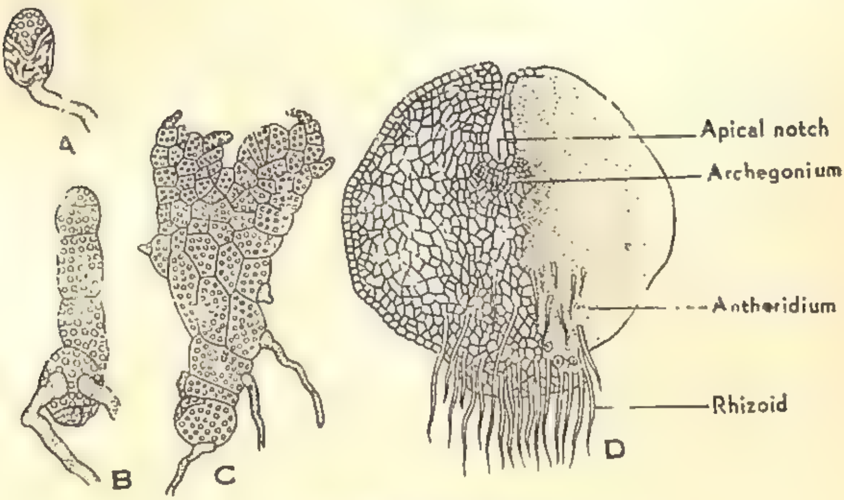


Fig. 364. *Polypodium*.
A—D, Stages in the development of the prothallus.

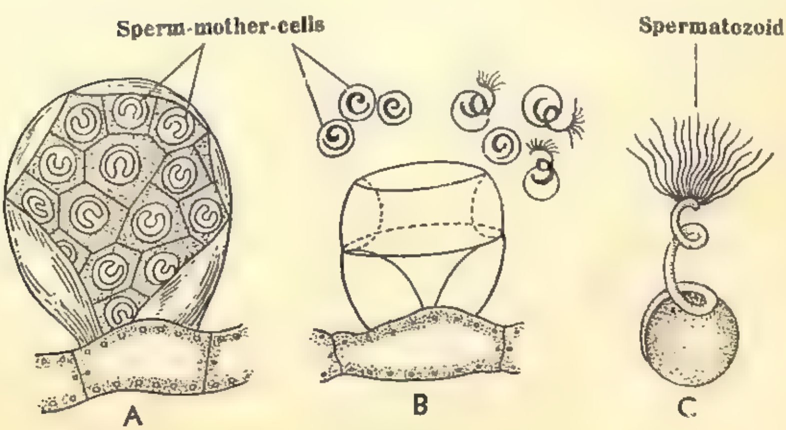


Fig. 365. *Polypodium*.
A, A mature antheridium; B, The same showing liberation of spermatozoids;
C, A spermatozoid.

of which a spirally-twisted, multiflagellate **spermatozoid** or **antherozoid** is produced. When mature, the antheridium opens at the top and the mother-cells are liberated; the spermatozoids set themselves free from the mother-cells and begin to swim in the film of watei already present on the surface of the prothallus.

Each archegonium consists of two parts: (1) a basal swollen portion, called the **venter** and (ii) an elongated upper portion, the **neck.** It contains only one elongated neck canal cell, one ventral canal cell and an **oosphere** or **ovum** or **egg.** When the

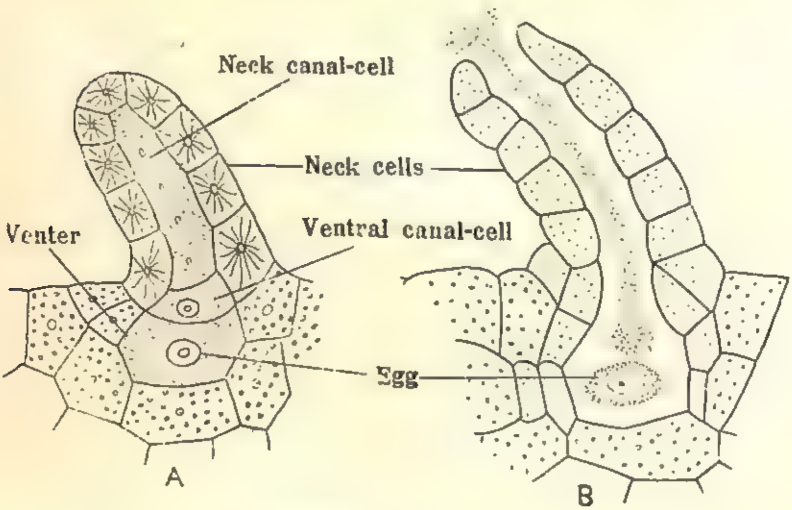


Fig. 366. *Polypodium.*
A, A young archegonium; B, A mature archegonium discharging mucilage containing malic acid.

archegonium matures, its neck canal cell and ventral canal cell become disorganized so that a thorough passage is established between the exterior and interior of the archegonium. This passage becomes filled with a mucilagenous substance containing malic acid.

The spermatozoids, set free from the antheridium, move about by means of their flagella in the film of water already present on the surface of prothallus and are attracted towards the archegonium by the malic acid given out by it for the purpose. The spermatozoids enter the canal, pass down the venter but only one fertilizes the ovum. This fertilized ovum on secreting a wall round itself becomes an

oospore. *With fertilization and formation of oospore, the sporophytic or diploid generation begins.*

It is to be noted that although the prothallus bears, as a rule, both kinds of sex organs, the antheridia and archegonia, cross fertilization generally takes place, i.e., spermatozoids developed on one prothallus pass into the archegonia of another. This is necessary because antheridium and archegonium are not developed on the same prothallus simultaneously.

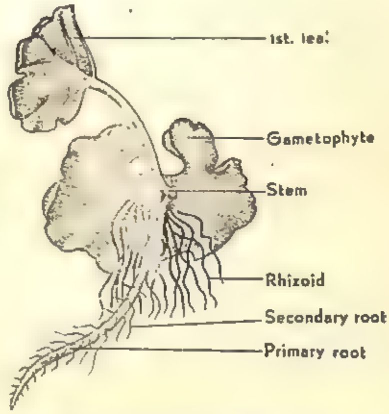


Fig. 367. *Polypodium.*
A young sporophyte still attached to the gametophyte.

The new sporophyte

The oospore gradually forms an **embryo** consisting of foot, root, primary leaf and stem, and from this embryo ultimately a new sporophyte is developed. After the establishment of new sporophyte the prothallus dies down and thus it becomes independent.

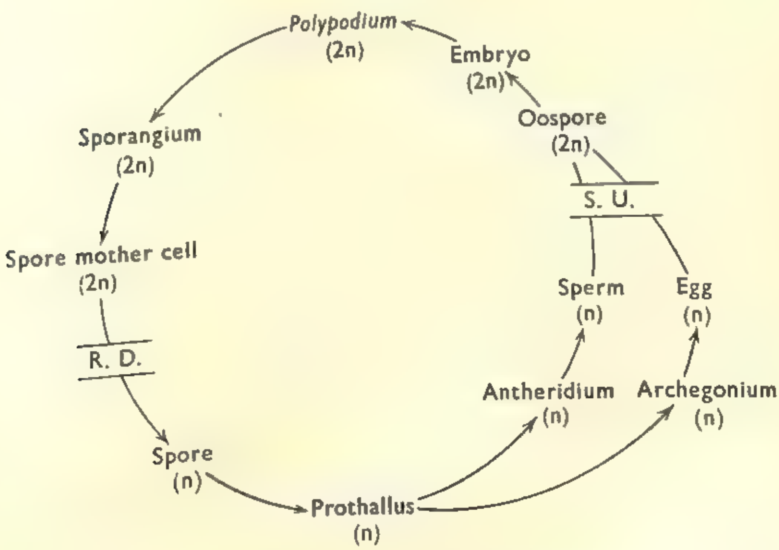


Fig. 368. Life cycle of *Polypodium.*

DRYOPTERIS

(Fam. Polypodiaceae)

Dryopteris, commonly known as male fern or shield fern, is generally found on the hills.

The common Indian species of *Dryopteris* is *D. filix-mas*.

The sporophyte

Dryopteris presents a robust appearance and when fully developed, it consists of a short, unbranched, stout and massive rhizome, which grows obliquely upwards and its apex rises but little above the surface of the soil. The stem is entirely covered over by numerous persistent leaf bases. There is usually no lateral branching,

Fig. 369. *Dryopteris filix-mas.*
Portion of a plant on the right and portion of a pinna with sori on the left.

but adventitious buds are developed at the bases of the leaves and these may separate to form new plants.

A transverse section of the rhizome shows two distinct regions: a large mass of ground tissue made up of parenchyma cells, and a vascular cylinder. The vascular cylinder is a typical dictyostele, with a number of meristeles embedded in the ground tissue forming an irregular ring. Each meristele is either round or elliptic in outline. The endodermis is two-layered, of which the inner one is not clearly distinguishable from the pericycle. The general mass of ground tissue lying internal to meristelar ring is the pith, while the tissue lying outside this ring constitutes the cortex. The cortex can be differentiated into two zones: an inner cortex made up of several layers of parenchyma cells with thin cellulose walls, and an outer cortex consisting of a few layers of cells with lignified thick walls. On the outermost surface there is the single-layered epidermis.

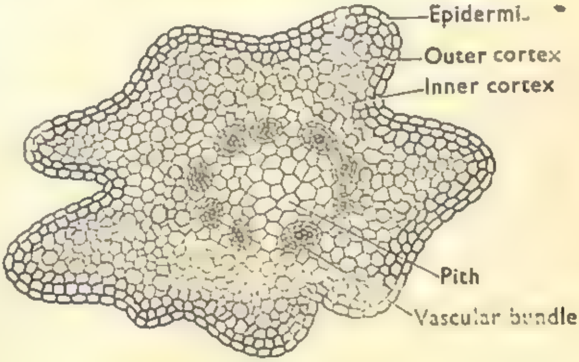


Fig. 370. *Dryopteris.*
T. S. of rhizome.

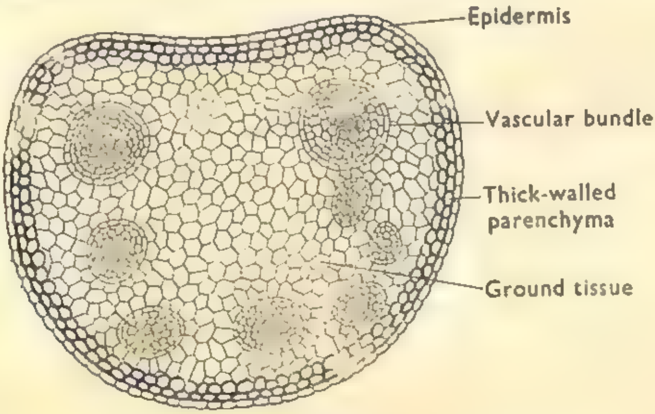


Fig. 371. *Dryopteris.*
T. S. of rachis.

From the basal part of each leaf, where it joins the rhizome,. usually there is three thin, wiry, dark-coloured adventitious roots are produced, the normal root of the embryo dying down very early. These adventitious roots branch extensively and monopodially, the branches appearing in acropetal order of succession. As a result, the rhizome is clothed with a dense mass of adventitious roots.

Internally, the root represents that of *Polypodium* in essential characters.

The leaves, often called **fronds,** are large (may be up to 1 metre in length), pinnately compound and much subdivided and when young they show characteristic circinate ptyxis. Annually a rosette of leaves unfolds towards the growing region of the stem. The lower portion of the rachis and also the large veins of the leaflets are clothed with numerous brown scales, known as the **ramenta,** which are characteristics of ferns.

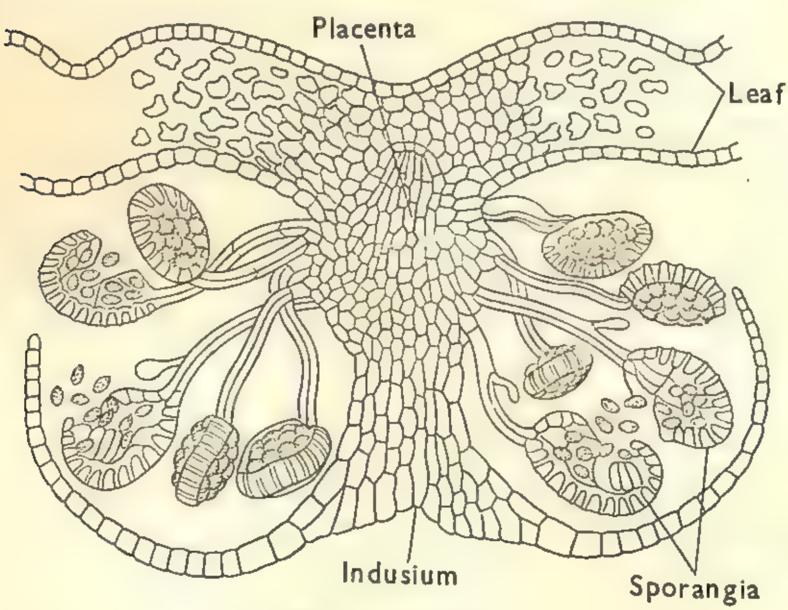


Fig. 372. *Dryopteris*.
T. S through a sorus.

A transverse section of the rachis reveals a number of isolated vascular strands embedded in a ground tissue giving rise to a somewhat horse-shoe shaped structure. The ground tissue is generally made up of several layers of parenchyma cells, of which a few outer layers are thick-walled. Each vascular bundle is hadrocentric.

During summer the sporangia are produced in groups forming small reniform **sori,** borne on the ventral surface of the pinnae of fertile leaves or **sporophylls.** The smaller pinnae usually bear only one or two sori each, while in the larger ones the sori are developed in two distinct rows, one on each side of the midrib. Each sorus is situated on a lateral vein and covered by a kidney-shaped **indusium.**

The structure of the sporangium as well as the process of fertilization are practically similar to those of *Polypodium* in essential details.

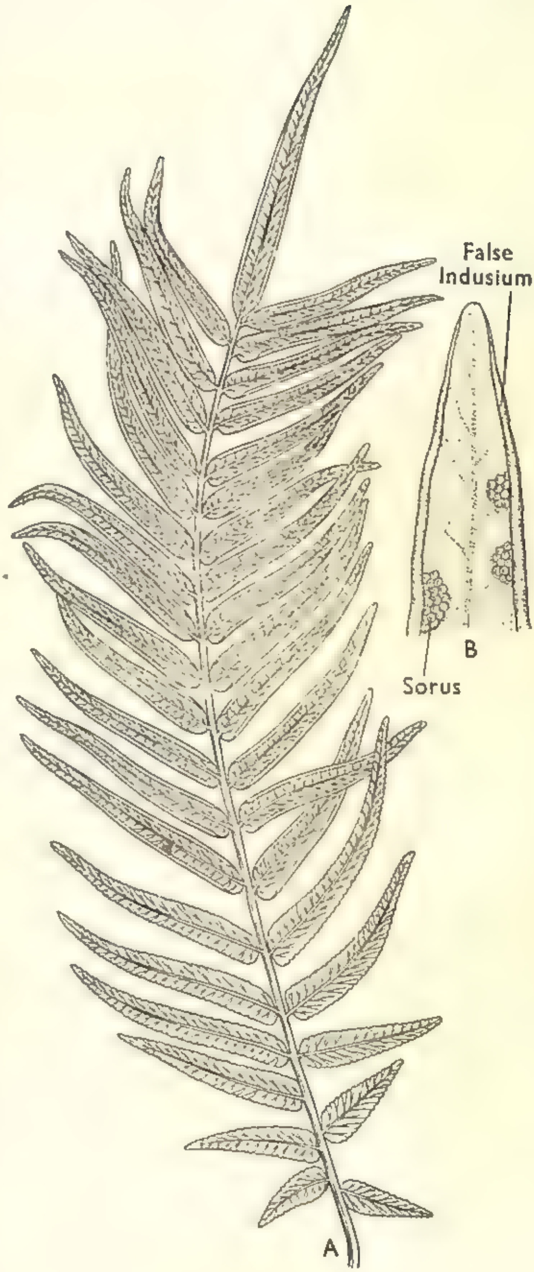


Fig. 373. *Pteris longifolia.*
A, Portion of a shoot; B, Portion of a pinna with coenosori.

PTERIS

(Fam. POLYPODIACEAE)

Pteris, a common fern, grows extensively in cool, moist and shady localities.

The common Indian species of *Pteris* are *P. longifolia, P. cretica, P. ensiformis, P. grandifolia,* etc.

The sporophyte

The rhizome may be either short and straight (as in *P. longifolia*, *P. cretica*, *P. ensiformis*, etc.), or long and creeping (as in *P. grandifolia*).

The internal anatomy of the rhizome is rather complicated and is very variable. Usually, in the cases of creeping rhizomes the vascular cylinder is a solenostele, but in the species with upright rhizomes it is a polycyclic dictyostele with prominent overlapping leaf gaps.

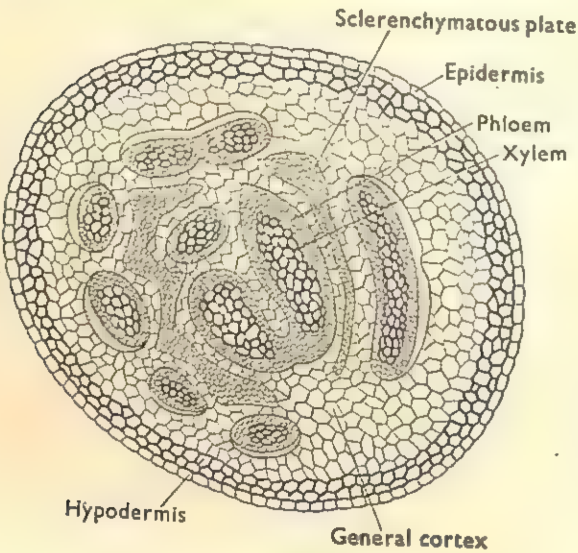


Fig. 374. *Pteris*. T. S. of rhizome.

The roots are adventitious in nature and develop from the rhizome. Internally, the root represents essentially the structure of that of *Polypodium*.

The leaves are variable and range from pinnate compound to decompound type. Scales and unbranched hairs are generally present at the leaf-bases as well as on the rhizomes forming **ramenta.** The leaves of the most commonly occurring species, *P. longifolia*, are imparipinnately compound and the pinnae are lanceolate in shape. The pinnae are sessile and situated laterally on both the sides of the rachis. Each pinna possesses a venation which is at first pinnate and then forked.

A cross section of the rachis reveals the presence of a single horse-shoe shaped hadrocentric bundle with exarch xylem embedded in the ground tissue, as in *Dryopteris*.

The sporangia are grouped together forming continuous linear sori, termed as **coenosori,** borne on the marginal connecting veins. As a rule, these coenosori are not produced near about the apices of the pinnae and their continuity may be interrupted at irregular

intervals. Each sorus is protected by the reflexed margin of the pinna itself, which forms a **false indusium.**

The structure of the sporangium as well as the process of fertilization are practically similar to those of *Dryopteris* in essential details.

ORDER 4. MARSILEALES

The Order Marsileales is characterized in having the sporangia produced within a specialized structure, called the *sporocarp*. The sporocarp-wall is produced by the modification of the leaf-blade. The sori borne within the sporocarp are of gradate type and the spores are heterospores.

The Order contains only one Family **Marsileaceae,** which includes three living genera: *Marsilea* (about 65 spp.), *Pilularia* (6 spp.) and the monotypic *Regenellidium.* All the members are hydrophytes. *Marsilea* and *Pilularia* are practically cosmopolitan in their distribution, while *Regenellidium* is endemic in Brazil.

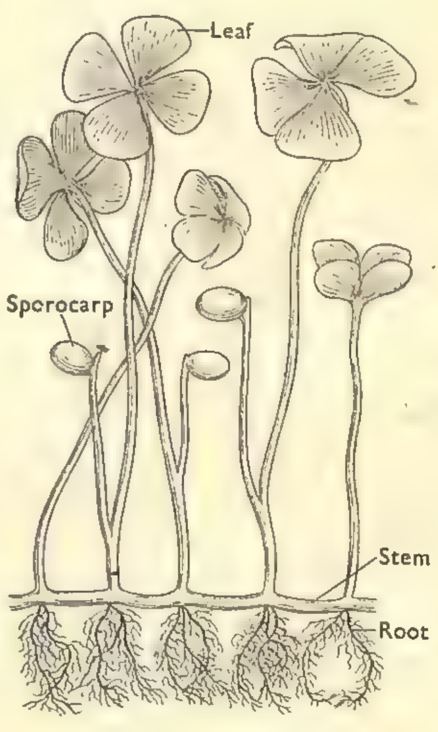


Fig. 375. *Marsilea.*
An entire plant with sporocarps.

MARSILEA

(Fam. MARSILEACEAE)

Marsilea, commonly known as 'water fern', grows in shallow water or in wet places, often creeping upon the banks and growing in all directions. A few species, however, grow in dry situations throughout the year. The genus comprises of 70 species. The common Indian species are *M. minuta, M. quadrifolia, M. condensata,* and *M. poonensis.*

The sporophyte

The stem is rhizomatous, dichotomously branched and creeps on or just below the surface of the substratum. The internodes may be short or long. On the upper side of the rhizome there are two rows of alternating erect leaves. The branches are either axillary or arising below or lateral to each leaf. Adventitious roots develop on the outer side of each node of the rhizome. The leaves are typically peltate and quadrifoliate, each with a considerably long petiole. Young leaves, towards the growing apex of stem, show characteristic circinate ptyxis. The veins in the awl-shaped

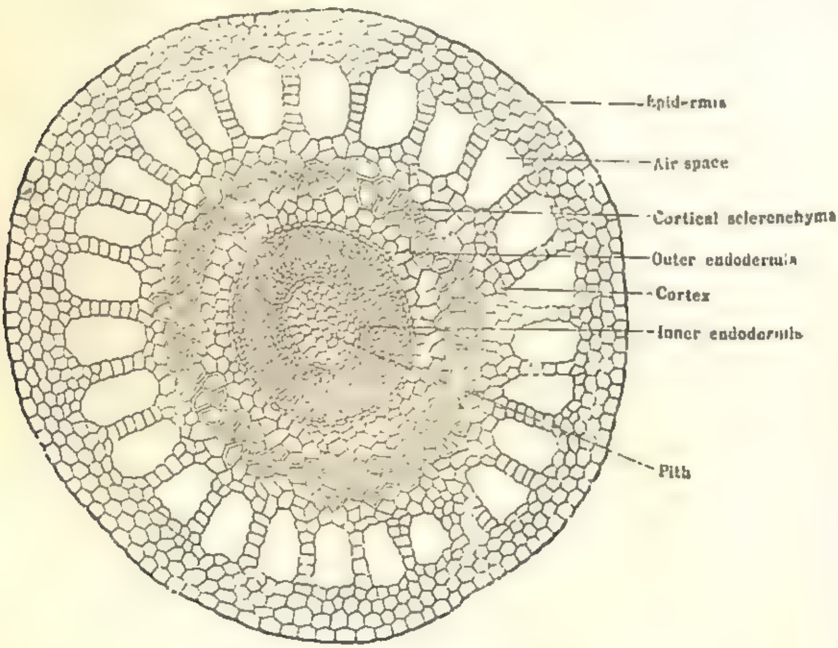


Fig. 376. *Marsilea.*
Transverse section of rhizome.

leaflets are dichotomously branched and are ultimately connected by short veinlets to form a reticulum.

Internally, the rhizomes of all species of *Marsilea* have an amphiphloic siphonostele, being limited internally and externally by endodermal layers, and with a central pith. The pith may be either parenchymatous or sclerotic, depending upon environmental conditions in which the plant grows, and is separated from the

inner pericycle by a single layer of parenchymatous endodermis. In some species the protoxylem elements are not recognizable. Inside the outer endodermis there is a single layer of parenchymatous pericycle. External to the outer endodermis lies a comparatively thick cortex extending upto the epidermis. This is differentiated

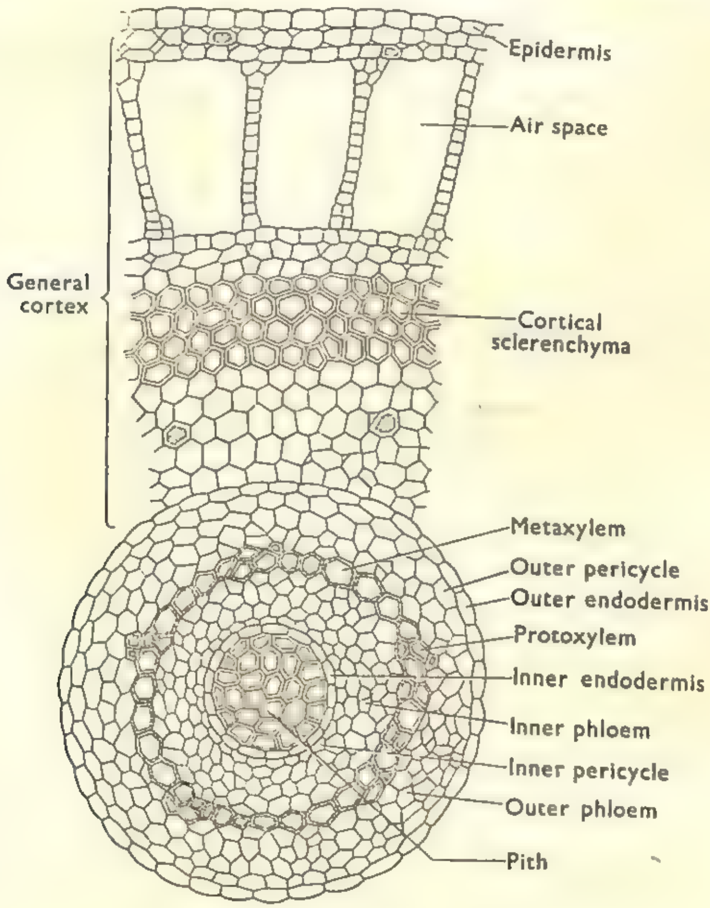


Fig. 377. *Marsilea*.
T. S. of rhizome (in part).

into an inner solid thin-walled or sclerotic parenchyma and an outer parenchyma with a single ring of conspicuous air space, being limited externally by one to several layers of parenchymatous tissue.

At the time of reproduction prominent reproductive structures,

known as **sporocarps,** which are usually borne laterally on short or long peduncles inserted a little above the base of the petioles (sometimes apparently adaxially or axillary). The sporocarps are stalked and somewhat bean-shaped to ovoid nut-like bodies. The wall is very hard and thick, strongly resistant to external influences and is capable of retaining its vitality for several years. The peduncle may be unbranched with a solitary terminal sporocarp, or in some species branches dichotomously and bears 2-20 or more sporocarps. It has generally been interpreted that the sporocarp of *Marsilea* is 'a modified fertile segment from the lower part of a leaf, but it has also been considered to be homologous with the whole leaf'.

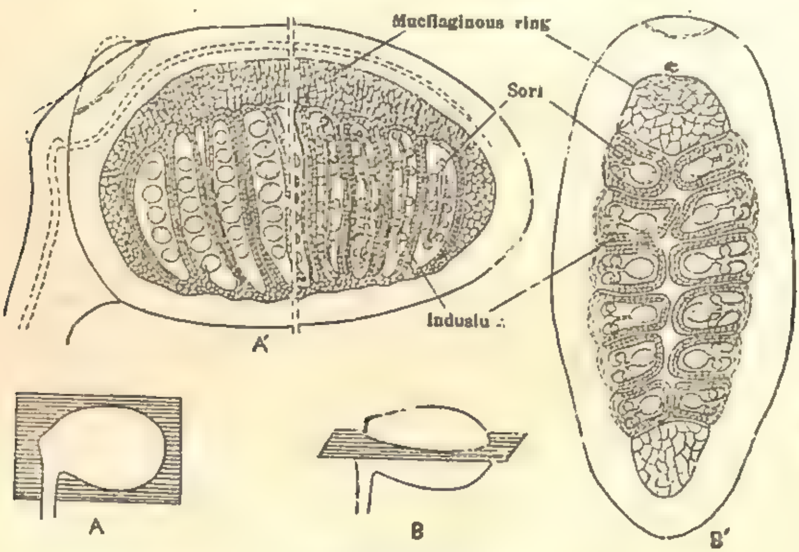


Fig. 378. *Marsilea*.
A-A', Vertical section through the sporocarp;
B-B', Transverse section of the same.

Within the inner wall of the sporocarp and attached to it, there are two rows of elongated, closely-packed **sori,** one on each side filling up the sporocarp-cavity, and these extend transversely to the longitudinal axis of the sporocarp. Each sorus is enclosed by a delicate **indusium.** *Marsilea* is heterosporous and each sorus contains a row of megasporangia surrounded by many microsporangia. These sori are attached to a mucilagenous tissue, which swells remarkably on coming in contact with water at the time of germina-

tion. All the mother-cells of the microsporangium undergo reduction division and form microspores. Within the megasporangium only one mother-cell matures and by reduction division forms a spore-tetrad, of which only one megaspore matures, while others degenerate. *With reduction division and formation of spores, the gametophytic or haploid generation begins.*

The gametophytes

When the spores attain maturity, the sporocarp germinates and opens in water along its ventral side and apex, splitting in a spreading bi-valved structure. The ring of internal mucilagenous tissue

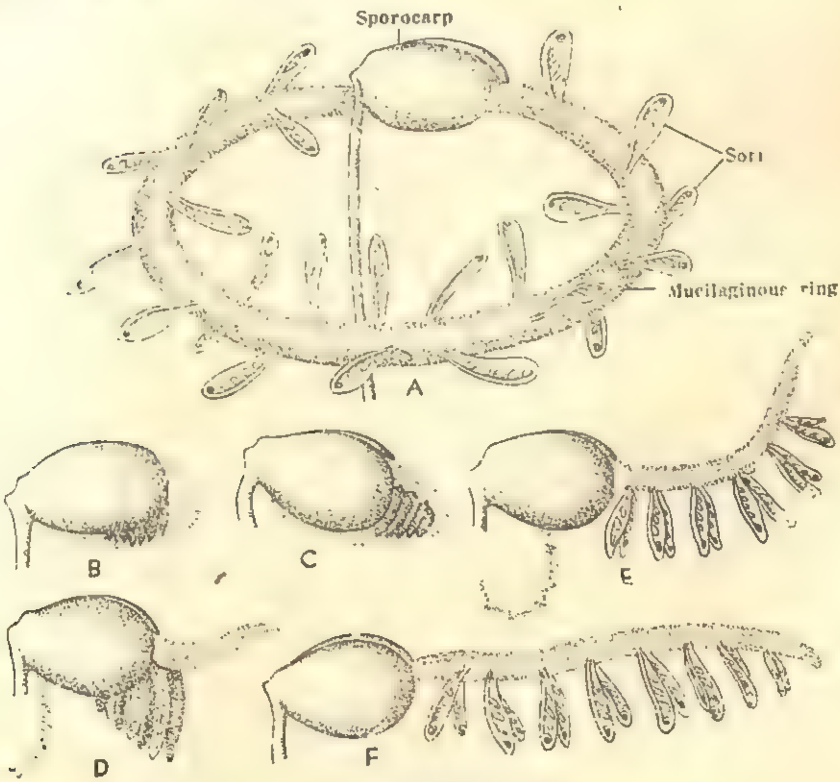


Fig. 379. *Marsilea.*
A-F, Successive stages in the germination of the sporocarp.

within the sori absorbs water, swells remarkably, comes out of the ruptured sporocarp and thus drags out the sori which are attached to the ring by their ends. Gradually the indusia and the sporangial

jackets undergo gelatinization and the spores remain embedded in the gelatinous matrix during early stages of germination.

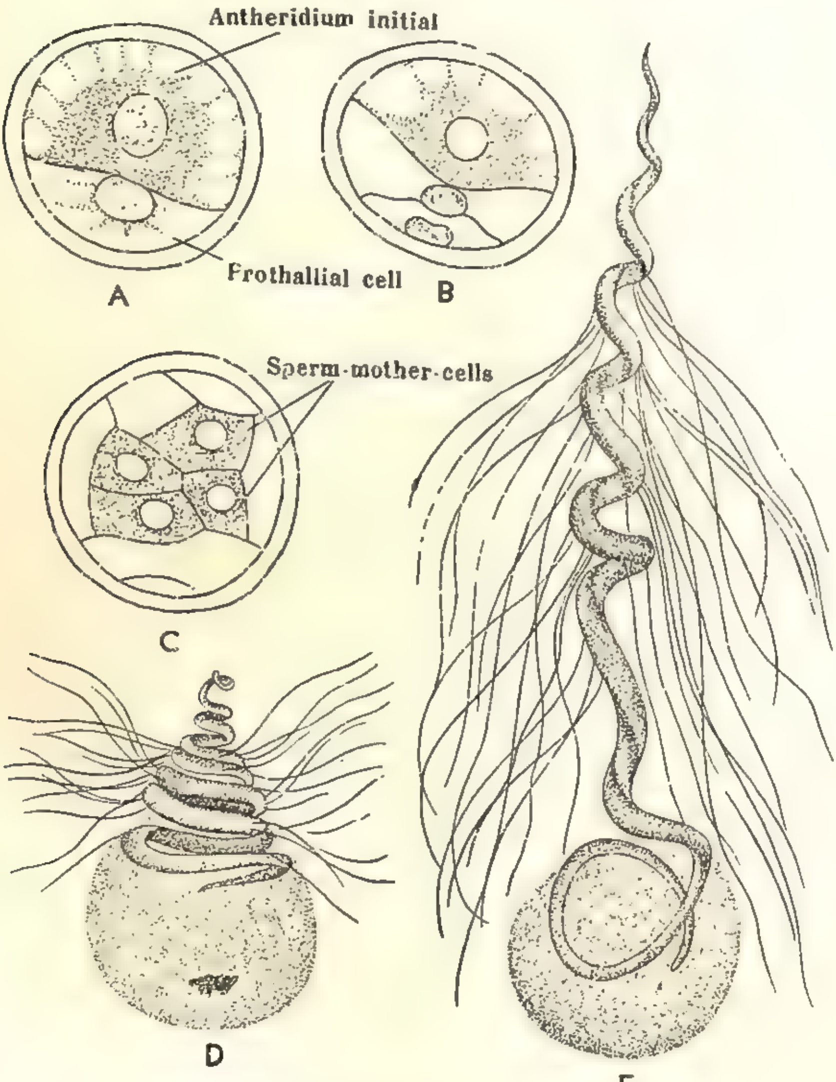


Fig. 380. *Marsilea.*
A—E, Stages in the development of spermatozoids.

Male gametophyte. The development of the male gametophyte from the microspore resembles that of *Selaginella* and *Isoetes.* It does not emerge out of the spore-wall. A small **prothallial cell**

is first cut off as usual, and a single antheridium is ultimately formed making up the whole gametophyte. The antheridium consists of a jacket of sterile cells surrounding two inner spermatogenous cells, by the successive divisions of which 16, multiflagellate, spirally-coiled, spermatozoids are produced. The spermatozoids are ultimately set free by the bursting of the spore-wall.

Female gametophyte. The megaspore germinates soon after it comes in contact with water. Its nucleus divides near its apex and a small apical cell is cut off by a wall. The large basal cell, with its undivided nucleus, contains abundant food materials,

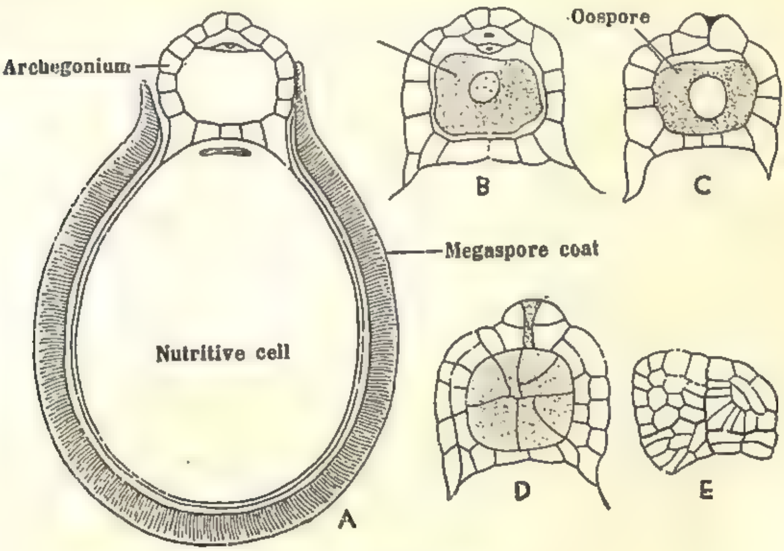


Fig. 381. *Marsilea.*
A—E, Stages in the development of embryo.

including starch grains, and is nutritive in function. The small apical cell protrudes through the megaspore-wall and forms a small group of cells, the gametophyte proper, bearing a small and simple archegonium. The archegonium is broad but low and has only one neck canal cell.

The spermatozoids swim towards an archegonium and only one finding its way down through the neck fertilizes the ovum and forms an **oospore.** *With fertilization and formation of oospore, the sporophytic or diploid generation begins.*

The new sporophyte

The oospore develops into an embryo consisting of a leaf, a root, a foot and the stem, and from this embryo the *Marsilea* plant is ultimately developed.

ORDER 5. SALVINIALES

The Order Salviniales is also heterosporous and the sporangia are developed within *sporocarps*, each sporocarp containing either a number of microsporangia or a solitary megasporangium. The sporocarp-wall is produced by the modification of the indusium.

The Order includes a single Family **Salviniaceae** with *two* living genera*: *Salvinia* (13 spp.) and *Azolla* (5 spp.). The plants are mainly inhabitants of tropical freshwaters.

SALVINIA

(Fam. SALVINIACEAE)

Salvinia is a free-floating hydrophyte and inhabits freshwater

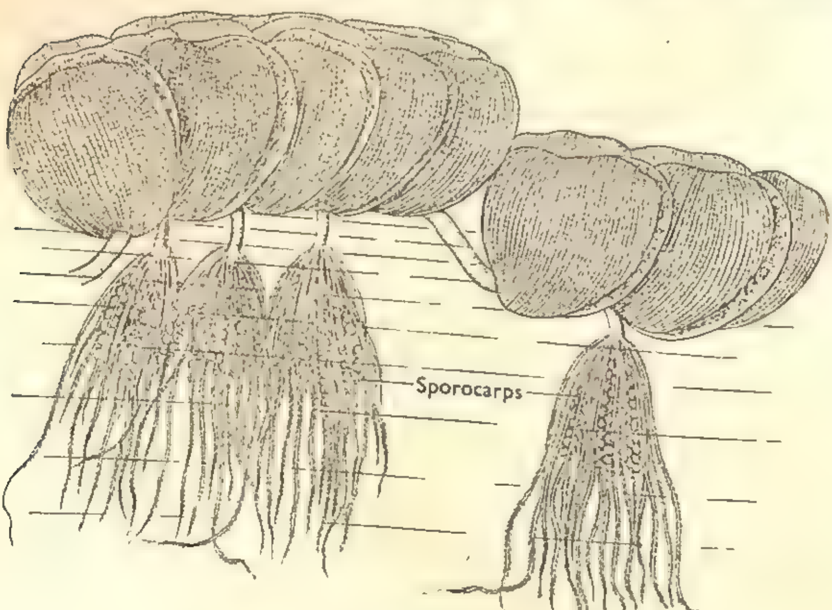


Fig. 382. *Salvinia cucullata*. Plant body.

* According to Christensen (1938) the two genera belong to two different Families.

pools, tanks and lakes gregariously. It is mainly an African genus, though a few species are very common in India.

The genus comprises of 10 species. The common Indian species are *S. natans* and *S. cucullata.*

The sporophyte

The stem is a branched rhizome attaining a length upto 10 cm. and the entire body is densely clothed with short-stalked or sessile leaves, arranged in whorls of three* (two lateral and one submerged). The plant is rootless but the submerged leaf gets highly dissected and covered with multicellular hairs and thus resembles the root-system. The two lateral leaves are covered with stiff hairs and papilose projections and are highly modified as floating organs.

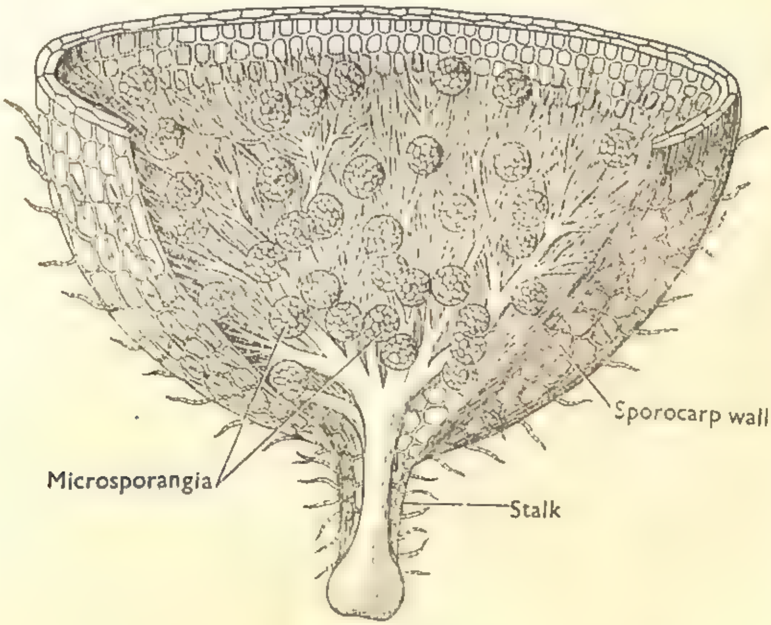


Fig. 383. *Salvinia.*
A sporocarp partially split open to show the microsporangia.

Internally, the rhizome has a siphonostele with greatly reduced vascular tissues and a broken cylinder of xylem.

* The whorl of three leaves at a node regularly alternate with another whorl of three leaves, thus giving rise to six rows of leaves although due to the arrangement of leaves these appear to be present in three rows only.

Some of the inner segments of the submerged leaves bear a number of **sporocarps** (4-20) in clusters or rows, which are sympodial in nature. A sporocarp is usually ovoid or globular in shape and its delicate wall is composed of only two layers of cells, developed from the indusium. Either a single megasporangium or a sorus of microsporangia is to be found within each sporocarp, but never a mixture of the two. The microsporangia develop in a typical leptosporangiate manner. Each microsporangium produces 64 *microspores*, all of which mature successfully, while in a megasporangium 32 *megaspores* are produced, of which only one attains maturity, the others aborting early. The cytoplasm, from the tapetum and the degenerating sister spores, forms a vacuolated, hard, complex layer around the mature megaspore and is known as the **perispore** or **epispore.** The microspores are provided with prominent tri-radiate markings, and around each the tapetal cytoplasm forms a hard, alveolate mass, known as the **massula.** On attaining maturity the sporocarps sink to the bottom, the walls undergo decay and the spores, generally enclosed by the sporangium wall, float on the surface of water.

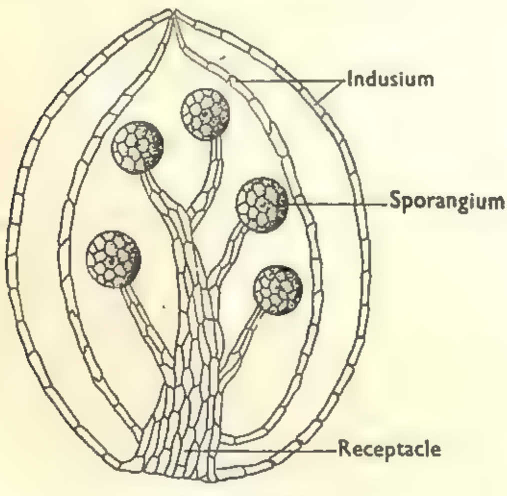


Fig. 384. *Salvinia.*
L.S. of sporocarp (Diagrammatic).

Vegetative multiplication takes place with the help of fragile stems, which get readily broken apart.

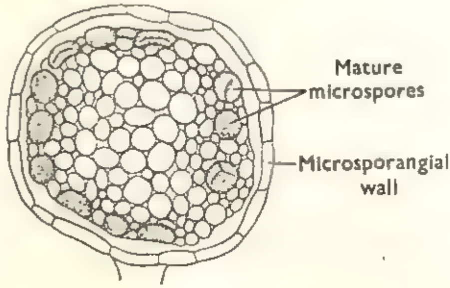


Fig. 385. *Salvinia.*
A mature microsporangium in sectional view.

The gametophytes

Male gametophyte. The microspores germinate in the massula while still enclosed within the sporangium. At first the spore enlarges and then it divides transversely into three cells, the lowermost one cutting off a minute **basal cell** which resembles the prothallial cell. The two upper cells undergo successive divisions and produce two **spermatogenous cells** and four **sterile cells,** each of the former giving rise to the **spermatocytes** in a cluster; each such cluster is regarded as representing an **antheridium.** The *antherozoids* are spirally-twisted and multiflagellate. On maturity, by the enlargement and elongation of the basal cell the entire gametophyte is pushed out of the sporangium.

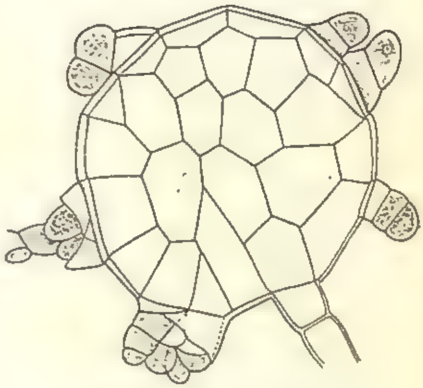


Fig. 386. *Salvinia.*
Developing male gametophytes emerging out of the microsporangium.

Female gametophyte. The megaspores float horizontally on the surface of water. The first division, which is a transverse one, results in a small, lenticular **apical cell** and a large **basal cell.** The former gives rise to a cushion of cells, on which develops the **archegonium,** while the nucleus of the latter one undergoes free nuclear division and functions as a reservoir of food. The perispore and the spore-wall finally

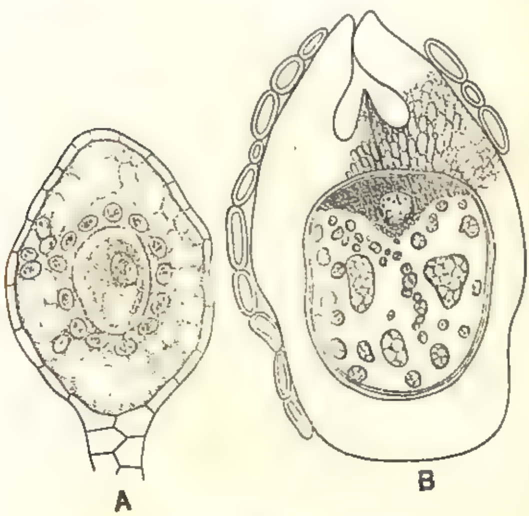


Fig. 387. *Salvinia.*
A, The surviving megaspore in a megasporangium; B, V.S. of a mature megaspore.

Fig. 388. *Salvinia*. L.S. of a sporocarp.

break open, the gametophyte protrudes out and turns green. The archegonia are deeply sunken, the neck projecting very slightly. There are a solitary neck canal cell, a ventral canal cell and an egg cell.

The new sporophyte

By fertilization the egg cell is converted into an **oospore.** The first division of the oospore is longitudinal or nearly so, giving rise to two unequal parts.

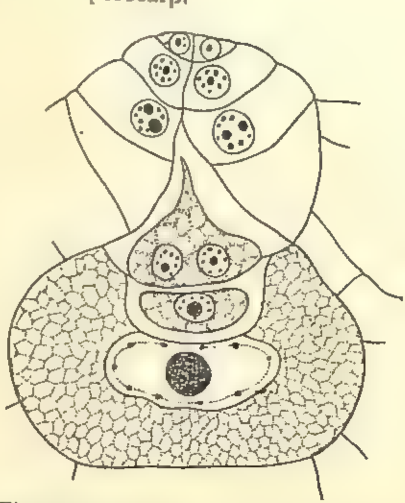


Fig. 389. *Salvinia*. An archegonium.

By subsequent divisions an *embryo*, with a foot, the first leaf and a stem apex*, is formed and ultimately produces a new sporophyte.

AZOLLA

(Fam. SALVINIACEAE)

Azolla is a free-floating plant occurring in freshwater pools, tanks and back waters. The genus comprises of 6 species, of which *A. filiculoides* can be regarded as a cosmopolitan one.

The common Indian species is *A. pinnata* (=*A. imbricata*).

No fossil representative is known from earlier than the Lower Caeneozoic bed.

Fig. 390. *Azolla pinnata*. Plant body.

The sporophyte

The sporophyte of *Azolla* looks more or less like the gametophyte of a leafy Jungermannia. It has a freely-

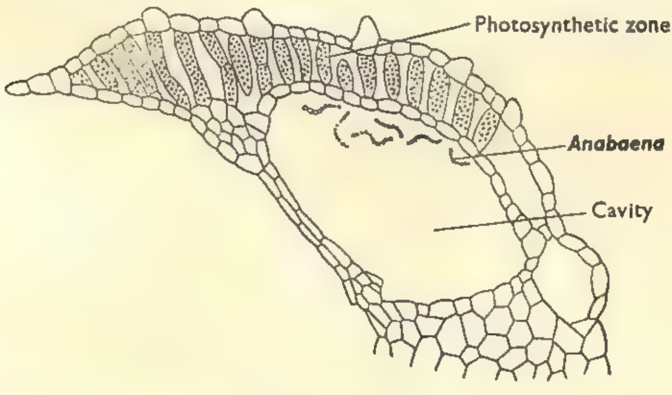


Fig. 391. *Azolla*.
L.S. through the dorsal lobe of a mature leaf.

* According to some workers the embryo possesses all the quadrants forming stem, leaf, foot and root, of which the last segment stops growing very early and cannot be distinguished from the foot.

branched delicate rhizome, which is horizontally floating, bearing solitary or clustered adventitious roots on the underside, and alternately arranged two-ranked leaves on the dorsal side. Each leaf is dorsiventrally lobed, the lobes being approximately of equal size; the thick dorsal lobe is green and aerial, while the thin ventral one is almost hyaline and submerged. This ventral lobe is believed to be helpful in absorbing water.

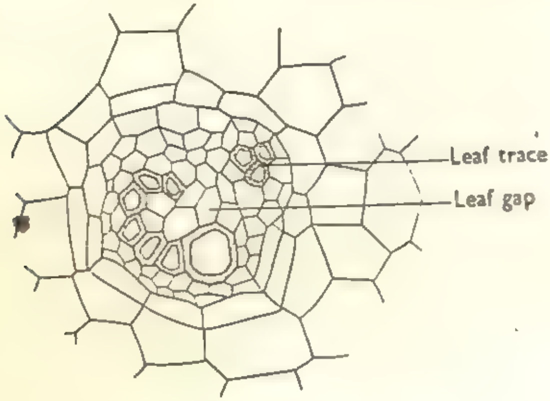


Fig. 392. *Azolla*.
T.S. of stem (in part).

On the lower surface of the dorsal lobe there is a conspicuous cavity harbouring the blue-green alga, *Anabaena azollae*. It has been demonstrated experimentally that this blue-green alga is capable of fixing free nitrogen for its host.

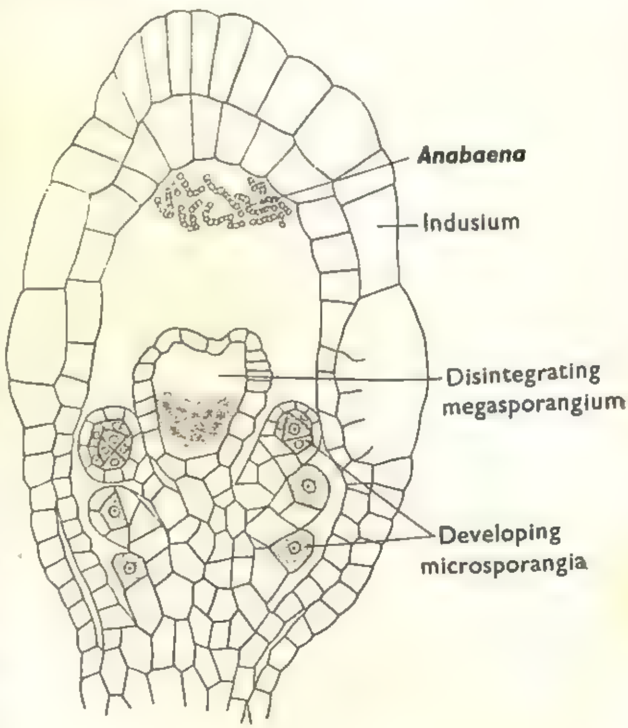


Fig. 393. *Azolla*.
L.S. through a developing microsporocarp.

Internally, the rhizome has an apparently siphonostelic cylinder, but it is practically impossible to differentiate the central cylinder from the cortex. The

vascular tissues are greatly reduced. The parenchyma cells in the cortical region are without intercellular spaces.

According to the species, 2-4 **sporocarps** are produced in the axil of the dorsal lobe of the lowermost leaf of a branch. Each sporocarp is borne terminally on a division of the submerged lobe and a one cell-layer thick marginal flap, developed from the upper lobe, covers all the sporocarps in the fashion of a hood. The sporocarp, as is characteristic of the Order Salviniales, develops from the indusium. The sporocarp bears either microsporangia or megasporangia, and depending on it, the sporocarps differ in their shape and size, the **megasporocarps** being larger than the **microsporocarps.** The microsporocarp contains numerous long-stalked **microsporangia,** while a single **megasporangium** is borne by a megasporocarp. The mode of development of the sporangia is of the leptosporangiate type.

Upto the sporangial initial stage all sporocarps behave in a similar manner. At first, a megasporangium is produced at the tip of a short receptacle. During the early stages of development this megasporangium contains 8 **spore mother-cells,** enclosed within a single-layered tapetum and also a single - layered wall. Later on, the tapetal cells break down, their protoplasm coalesce forming a multinucleate **periplasmodium,** which surrounds the spore mother-cells and quickly pushes between them. In the meanwhile, the receptacle has grown much stouter bearing a number of young microsporangia from its sides. Subsequent to this, in a sporocarp either the microsporangia or the megasporangia mature, the other kind of sporangia undergoing abortion. In a mature microsporangium there are 64 microspores formed. At first the

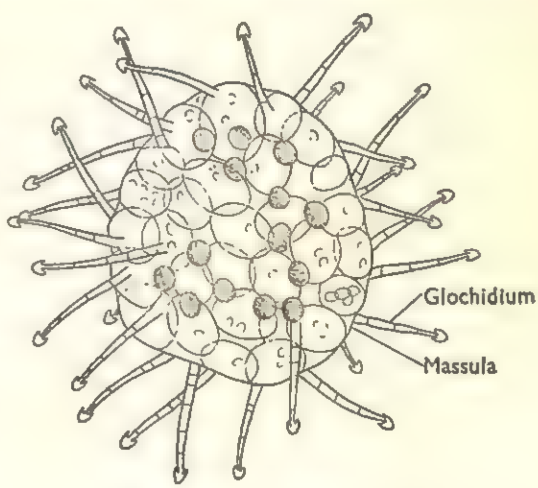


Fig. 394. *Azolla.*
A microsporic massula with glochidia.

microspores lie scattered in the cytoplasmic mass, but within a very short time they occupy a peripheral position and remain in a more or less uniformly distributed condition. After this stage, the periplasmodium forms 4 or more quadrately-arranged, alveolated bodies called **massulae,** embedded within each of which are to be found a number of microspores. In some species, like *A. filiculoides*, *A. caroliniana*, etc., the massulae develop a large number of elongated hook-like processes, known as **glochidia,** on their surfaces.

In a megasporangium at first 32 megaspores are developed from 8 spore mother-cells. Finally, however, only one attains maturity, while all others degenerate. The single surviving megaspore lies embedded in a large massula at the base of the sporangium and enlarges considerably. The other three massulae may contain one or more abortive megaspores. When the megaspore attains maturity the megasporangium as well as the indusium rupture transversely, the megaspore, embedded in the massula, gets liberated, and with this massula the distal part of the indusium, the ruptured megasporangial wall and the three other massulae still attached. In a like manner, by the breaking down of the indusium and the rupture of microsporangial wall the microspores, embedded in the massulae, are also liberated. The glochidia of the microsporic massulae help in anchoring them to the megasporic massulae. Subsequent to this the gametophytic development takes place.

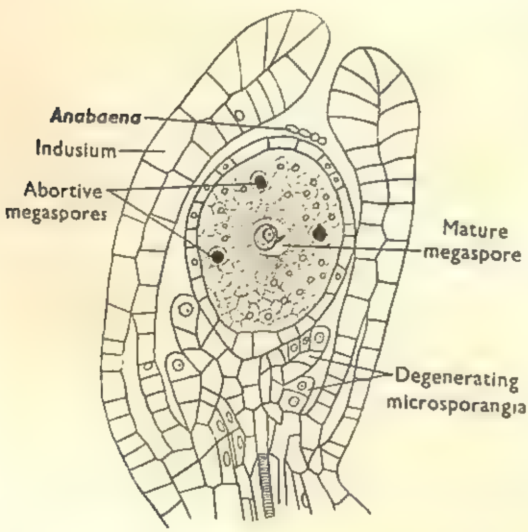


Fig. 395. *Azolla.*
L. S. through a developing megasporocarp.

The gametophytes

Male gametophyte. A microspore develops into a male gametophyte while still embedded within a massula. At first, the

outer spore-coat bursts open, and the cytoplasm along with the nucleus protrudes out, being still enclosed within the inner coat. This protruded portion is cut off by means of a transverse septum and functions as the solitary **antheridial initial,** which ultimately gives rise to an antheridium containing 8 sperm mother-cells, each of which gives rise to a single spermatozoid.

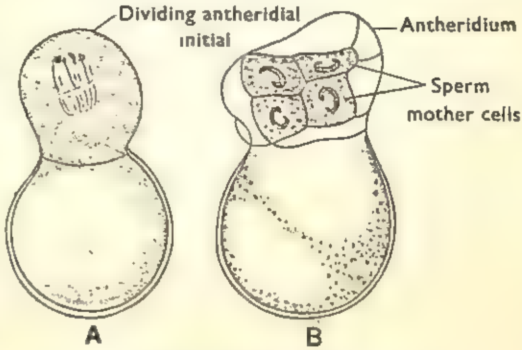


Fig. 396. *Azolla.*
A—B, Stages in the development of the male gametophyte.

Female gametophyte. A megaspore develops into a female gametophyte. The megaspore-nucleus at first enlarges and then undergoes division, following which a

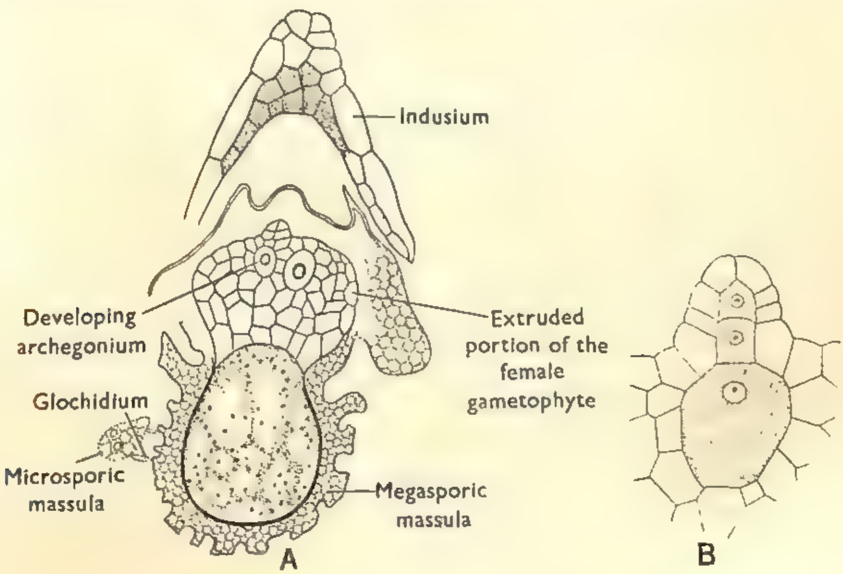


Fig. 397. *Azolla.*
A, A mature female gametophyte; B, An archegonium.

lenticular cell is cut off at the upper region of the megaspore. The large basal cell undergoes no further division but becomes

multinucleate and is nutritive in function. The upper lenticular cell undergoes divisions and one of the median cells functions as the **archegonial initial.** Very soon after the formation of this archegonial initial, the megaspore coat ruptures and the developing female gametophyte protrudes out. On this exposed region the archegonium is borne.

The new sporophyte

As a result of fertilization the egg cell in the archegonium is converted into an **oospore.** This oospore becomes elongated vertically and undergoes a transverse division at first. By subsequent divisions the embryo forms a quadrant, from which develop the first leaf, the stem, the root and the foot. From this embryo ultimately a new adult sporophyte is established.

Origin of Seed Habit

The dominant plants of the present day are the Gymnosperms and the Angiosperms. It seems certain that the dominance of these groups of plants over the Vascular cryptogams, which reproduce by means of spores, is mainly due to their acquisition of the method of reproduction by seeds. In the cryptogamic type of reproduction, the spores, after liberation from the sporangium of the parent plants, produce very delicate sexual plants,—the gametophytes. The survival of these gametophytes, as well as their sexual reproduction, are mainly dependent on the presence of moisture, and as such is a matter of chance. In the seed plants, however, the spore, which produces the megagametophyte is retained within the sporangium, and once the male spore, which produces the microgametophyte, comes in contact with the micropyle or the stigma. Further developments and fertilization are carried out within the integuments and are not at all dependent on environmental factors.

The process of the evolution of seed is thought to have commenced with an ancient homosporous form, which has given rise to the heterosporous condition. Most botanists regard the heterosporous condition as characteristic of all seed plants. The pollen is presumed to develop from a microspore, while the embryosac from the megaspore. The occurrence of many comparatively small spores within the megasporangia in *Selaginella* suggests a condition possibly not far advanced beyond the homosporous state. On the other hand, the sporangia with a fewer but comparatively larger

spores, indicate an advance in the direction of seed habit. Further, *Selaginella rupestris* and *S. apus* have progressed a long way in the direction of seed habit, as the megaspore in these cases is retained within the megasporangium, and the megaspore, while still within the sporangium, develops archegonia and forms embryo with roots and cotyledons. Thus, *Selaginella* is considered by many morphologists to illustrate the transformation from the strictly cryptogamic condition to the seed habit, that is, it shows the replica of stage through which the ancestor of the seed passed during its process of becoming a seed.

Thomson (1927, 1931, 1934) from his comparative studies of the sizes and other characteristics of pollen spores and seed spores concluded that seed plants are heterosporous and have evolved from homosporous ancestors, and *it is the heterothally and not heterospory that constitutes the important feature of the seed plants.*

Halle (1935) considered the terminal position of the primitive cupulate seed of the early lower carboniferous age, as significant and derived them from the terminal spore cases of the Psilophytales.

As long ago as 1904 Miss Bensen suggested that the cycadofilicean seed may be interpreted as a synangium in which excepting a single sporangium, all are sterile. This means that the 'seed state' was preceded by one in which a sporangium was closely encircled by a ring of sporangia, and these sporangia became sterile and formed the integument by fusion. Walton has very recently simplified this concept and suggests that the encircling elements were not sterile sporangia, but sterile branch tips. There are many fossilized plant remains known to support Walton's hypothesis.

Economic Importance of Pteridophytes

In comparison with the seed-bearing plants, the pteridophytes are less important from the economic standpoint of view. *Lycopodium* and *Selaginella* are chiefly grown as ornamental plants and are utilized in the preparation of christmas wreathes. Spores and stems of *Lycopodium* have got some medicinal importance, the former also being used in making fireworks. Species of *Selaginella*, e.g., *S. caesea*, and *S. wildenovii*, are used in decoration, because the leaves are remarkable for their metallic and many-hued tints, specially bronze and bluish colours, the latter being very uncommon among plants in general. *S. serpens* is well known for the

periodic changes in the colour of its leaves. *S. lepidophyla* and *S. pilifera* are sold as curios under the name "Resurrection plants". Ducks and other aquatic animals feed upon the corms of *Isoetes*. In early days people used *Equisetum* for polishing wood, floors and cooking utensils. The ferns are mostly ornamental plants of gardens and greenhouses. Some of them are used in the preparation of bouquets and are also placed in the buttonholes. Some species possess so dense and prominent epidermal hairs, that they are sometimes employed as stuffing material. In some tropical countries stems and leaves of tree ferns are used for building purposes. Some genera, like *Pteris*, *Ceratopteris* and *Marsilea*, are edible. The rhizomes and leaf bases of *Dryopteris filix-mas* are used in medicine as a taenifuge. Practically, all the members of the pteridophyta have contributed extensively to coal formation.

CHAPTER VI

GYMNOSPERMS

The idea of gymnospermy, as opposed to angiospermy, was first proposed by Robert Brown (1827). Since then, the question, which is not still clearly answered, is whether the group as a whole is monophyletic or polyphyletic in origin. The majority of workers, however, are of opinion that it is not monophyletic. Further, as the gymnosperms have been distinguished from the angiosperms mainly on the basis of the seed-character alone, they are to be considered as constituting an artificial group.

Whatever may be the validity or nature of the origin of the group, the gymnosperms or 'naked-seeded' plants are the most primitive of all seed-plants, as indisputable records of gymnosperms have been found in the Devonian (perhaps in the Silurian as well), whereas the angiospermous remains have been recorded only from the Jurassic onwards.

The gymnosperms are regarded as an intermediate group between the pteridophytes and angiosperms. The plant always represents the sporophyte, and is heterosporous. *The sporophylls are generally aggregated into cone-like structures or strobili*, which are usually unisexual, and do not bear any accessory whorl. In the gymnosperms, *the carpels do not unite to form a closed chamber or ovary*, but *the megasporangium or the ovule is borne directly on the surface of the megasporophyll* as in the case of pteridophytes, and the *pollinaton is direct*, i.e., the pollen grains are transferred directly on the micropyle of the ovule. As in the heterosporous pteridophytes, *two kinds of gametophytes are produced, but they are highly reduced* as in angiosperms. Archegonia are still present. The fertilization is effected by means of motile spermatozoids in lower gymnosperms, but in higher ones by means of non-motile gametes. Unlike the angiosperms, the endosperm is normally formed directly from the megaspore before fertilization is effected; as such, it is a haploid tissue, and is regarded as the female gametophyte in gymnosperms. As the carpel or carpels do not unite to form an ovary, the seeds are naked, and *there is no such organ as fruit* in the gymnosperms.

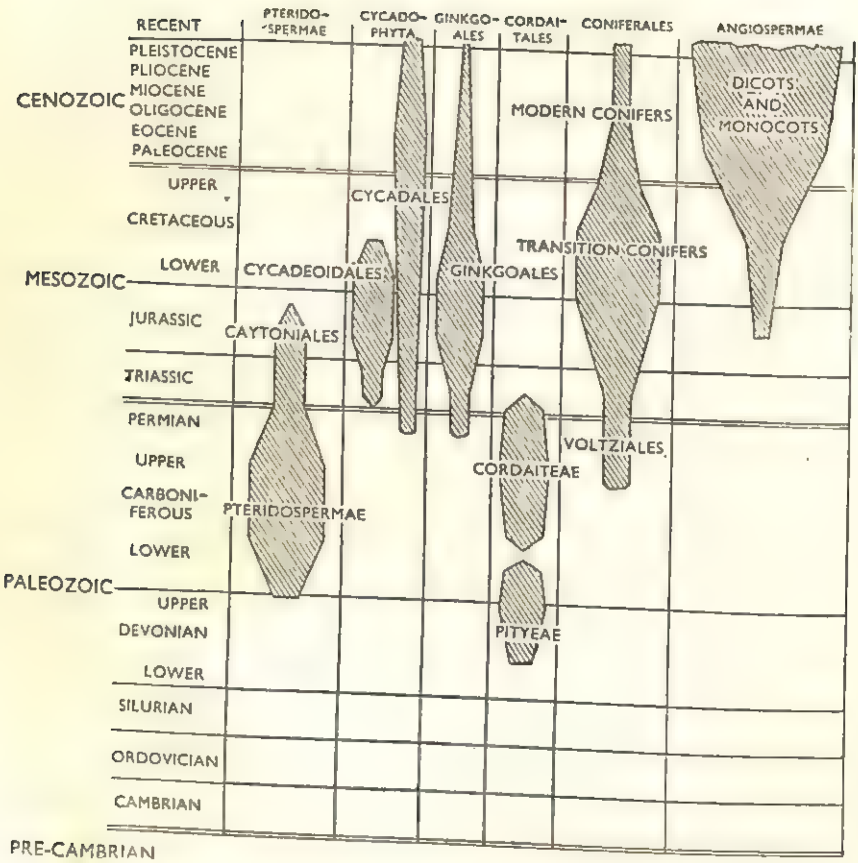


Fig. 398. Distribution of Gymnosperms in the geological periods

Classification of Gymnosperms

Of the different systems of classification, the one proposed by Prof. Chamberlain is adopted here. He divides the group into **Cycadophyta** and **Coniferophyta,** basing on the differences in the morphological and anatomical characters. The former section is characterized by plants of comparatively smaller size with unbranched stems, pinnately compound leaves, thick cortex, scanty wood, large pith, and generally simple cones. The Coniferophyta, on the other hand, are marked by having comparatively larger plants with extensively branched stems, simple leaves, scanty cortex, thick wood, small pith, and usually simple male cones and compound female ones.

The Cycadophytes are divided into *three* Orders—(1) **Cycadofilicales** (extinct), (2) **Bennettitales** (extinct), and (3) **Cycadales** (both extinct and living). On the other hand, the Coniferophytes include *four* Orders—(4) **Cordaitales** (extinct), (5) **Ginkgoales** (both extinct and living), (6) **Coniferales** (both extinct and living), and (7) **Gnetales** (both extinct and living).

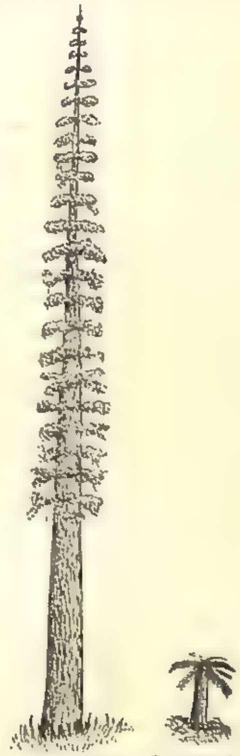


Fig. 399. Showing relative sizes of a member of the Cycadophyte and another belonging to the Coniferophyte.

ORDER 1. CYCADOFILICALES

In the year 1877, Grand Eury first discovered a few species of Cycadofilicales, which later on went by the name of the form genus* *Myeloxylon.* In 1887, Williamson suggested that these plants were intermediate between ferns and cycads in their characters. With the discovery of the fact that *Lagenostoma lomaxi* belongs to the stem of *Lyginopteris oldhamia* by Oliver & Scott in 1903, the name **Pteridospermae** was proposed for the seed-bearing Cycadofilicales. The

* Vide General Botany (2nd Ed.), page 769.

seed-bearing habit of the Pteridosperms was again verified next year by Kidston in *Neuropteris heterophylla*.

The Cycadofilicales or Pteridosperms are popularly known as 'seed ferns'. Though a few petrified stems have been discovered in the Devonian, yet no positive seed has been obtained before the Lower Carboniferous is reached. The plants first appeared in the Devonian, became very prominent in the Carboniferous, gradually declined during the Permian, but a few survived even upto Mid-Jurassic. The best known Cycadofilicales are reported from Great Britain.

Some of the well-known Indian members of the Cycadofilicales are *Glossopteris indica, G. communis, Gangomopteris cyclopteroides, Vertebraria indica, Thinnfeldia* sp., etc.

The characters of Cycadofilicales are as follows :

(1) Plants megaphyllous with large leaf traces.
(2) Primary xylem well-developed, usually mesarch or exarch stele and leaf traces.
(3) Secondary wood and phloem present, tracheids bear bordered pits, which are on the radial walls and are usually multiseriate.
(4) No definite distinction between male and female sporophylls with the vegetative frond, and there is no cone-formation.
(5) The leaves have resistant cuticle.
(6) Seeds are of cycadophytic type with a definite pollen chamber and a well-developed vascular system.

The Cycadofilicales have been divided into *two* major groups: the *Palaeozoic Cycadofilicales* and the *Mesozoic* ones. The former is further divided into *three* families, viz., **Lyginopteridaceae, Medullosaceae,** and **Calamopityaceae,** while the latter also consists of *three* families, viz., **Peltaspermaceae, Corystospermaceae,** and **Caytoniales.** Of the six families mentioned above, the most extensively studied one is Lyginopteridaceae.

A brief account of each of the families is given below:

1. **Lygniopteridaceae.** In the family the leaves are of the filicoid type, and the stem is of monostelic organization. The leaf traces and foliar bundles are single or double; the xylem is mesarch. Seeds are of cycadean type, and the cupule is present. The best known lygniopterid is *Calymmatotheca hoeninghausi*.

2. **Medullosaceae.** In this family the stem is polystelic, and many bundles are scattered in the petiole. Seeds are large.

3. **Calamopityaceae.** This is the oldest and the largest of all the families of Pteridosperms. The stem is monostelic, and scattered bundles are present in the petiole

4. **Peltaspermaceae.** The leaves in this family are small, bipinnate, and the rachis is characterized by swellings. The microsporophyll is branched, and microsporangia open longitudinally, and smooth pollens are discharged.

5. **Corystospermaceae.** The leaves in this family are linear-lanceolate and the seeds are characterized by ovoid, elliptic shape, and curved bifid micropyle.

6. **Caytoniales.** This family is characterized by leaves formed usually in two (occasionally three) pairs. Anatomically it has transfusion tissue and mesophyll with palisade layer. The pollen grains show a symmetrical bilobed structure, and these are winged. The ovules are orthotropous, and the nucellus is free from the integument except at the base. This is an advanced character. Formerly the Caytoniales were compared with the Angiosperms, but later on it was found out that members of this family are essentially gymnospermous.

CALYMMATOTHECA

(Fam. Lyginopteridaceae)

The best known lyginopterid is *Calymmatotheca hoeninghausi*, which was previously described under the names of several form genera: the stem was known as *Lyginopteris oldhamia*, the root as *Kaloxylon hookeri*, the petiole as *Rachiopteris aspera*, the leaf as *Sphenopteris hoeninghausi*, the stamen or pollen-bearing organ as *Telangium* sp. (=*Crossotheca* sp.), and the ovule or the seed as *Lagenostoma lomaxi*.

The sporophyte

The stem is long and slender with a presumed climbing habit, and bears spirally-arranged fern-like leaves. The frond is compound with a gland, and the rachis divides equally. The pinnae are oppositely arranged.

The anatomy of the stem shows a large pith, which is parenchymatous, and stone cells in groups forming **sclerotic nests** are present. The mesarch primary wood surrounds the pith, and the protoxylem is surrounded by metaxylem.

The xylem of the root is mesarch, and undergoes secondary growth.

In the petiole the xylem is completely surrounded by the phloem. The anatomical structure of the leaf is not much different from that of the living ferns. The epidermis is cuticularized, and the palisade and spongy parenchymas are present. The stomata are situated on the lower surface.

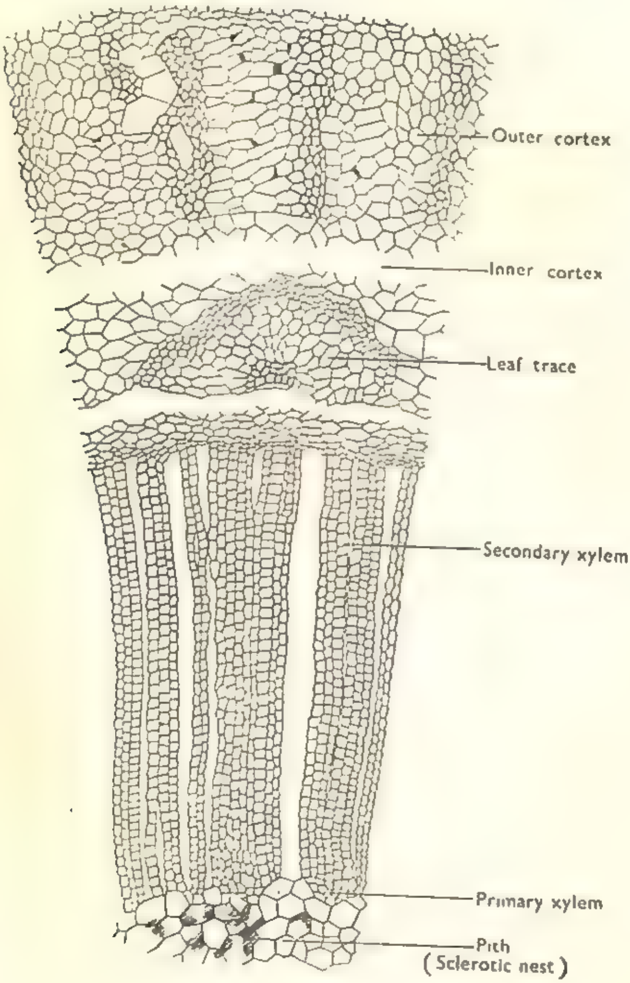


Fig. 400. *Calymmatotheca*.
T. S. of stem.

The stamen

The entire structure somewhat resembles the stamen of *Araucaria*. The fertile part is flattened into a paddle-shaped structure bearing a few pendant bilocular sporangia at its margin. In all probability

the pollen grains did not give rise to pollen tubes, and the sperms would have been of the cycad type.

The seed

The seed is small, terminal and barrel-shaped. It is orthotropous and symmetrical in nature with a simple set of vascular supply. It is surrounded by a glandular cupule, which can be compared to that of

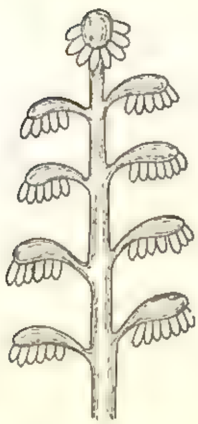


Fig. 401. *Telangium* (=*Crossotheca*).

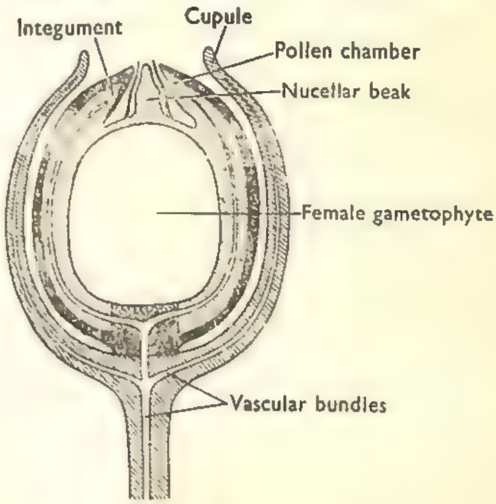


Fig. 402. *Lagenostoma*. Median longitudinal section through the ovule and the cupule.

Juglans, *Fagus*, and other living members of the Cupuliferae. The nucellus is free from the integument only at the tip, and has a conspicuous pollen chamber.

Very little is known about the female gametophyte, because it is hardly preserved.

ORDER 2. BENNETTITALES (=CYCADEOIDALES)

The Bennettitales, or the Cycadeoidales, which resembles the modern cycads in many respects, appeared first in all probability in the Triassic*, flourished very luxuriantly in the Middle or Late Jurassic, and then went on declining in the Cretaceous. It is believed that this Order arose side by side with the living Cycadales from a pteridospermous stock. The fossil remains are distributed

* Chamberlain believes that they appeared first in the Upper Carboniferous.

extensively throughout the United States, Mexico, different parts of Europe, as well as India.

The Bennettitales includes *two* families: **Williamsoniaceae** and **Cycadeoidaceae,** the former being much more older than the latter. The most important genus belonging to the Williamsoniaceae is *Williamsonia*, and that of the other is *Cycadeoidea* (=*Bennettites*).

The common Indian Bennettitales are *Williamsonia* (*W. sewardiana*, *W. indica* and *W. santalensis*), *Ptilophyllum* (*P. acutifolium* and *P. cutchense*), *Otozamites* (*O. bengalensis*), *Nilssonia* (*N. princeps*, *N. brindabunensis*, *N. rajmahalensis*, *N. morisiana*, *N. medlicottiana* and *N. fissa*), *Bucklandia* (*B. indica* and *B. sahnii*), *Dictyozamites* (*D. falcatus* and *D. indicus*) and *Pseudotenuis* (*P. footeana*).

Fig. 403. *Williamsonia sewardiana*. (Redrawn after Sahni).

WILLIAMSONIA

(Fam. WILLIAMSONIACEAE)

The most complete and well-known species of *Williamsonia* is *W. sewardiana* described by Prof. Sahni from the Jurassic (Upper Gondwana) of India in the Rajmahal Hills. The name is based more upon the fructification than the entire plant, whose stem is known as *Bucklandia indica*, and the leaf as *Ptilophyllum cutchense*.

The sporophyte

The plant body of *W. sewardiana* is a small, stout tree resembling a miniature living *Cycas*. The trunk is columnar,

bearing a cluster of pinnate compound leaves at its top. Intermingled with the leaves are scales, which leave small scars on the stem. There are lateral shoots, which are constricted at their bases. This suggests that they broke away, and served as propagative shoots. The leaf-bases formed an armour around the stem.

Internally, the pith of the stem is enclosed by a xylem ring. Tracheids of scalariform type are noted, and multiseriate bordered pits are present. The xylem rays are variable from uni- to multiseriate type. The protoxylem is endarch, and secretory sacs are present in the cortex as well as in the pith.

The flower

Flowers are produced on short-branched lateral shoots, which project beyond the armour of leaf cushion. Each flower is unisexual and ovulate, having a receptacle bearing the stalked ovules intermingled with *interseminal scales*. The nucellus of the ovule is enclosed by an integument, which prolongs into a micropylar beak.

CYCADEOIDEA (=*BENNETTITES*)

(Fam. Cycadeoidaceae)

The sporophyte

The main stem is ovoid or shortly columnar, stout, and covered by an armour of persistent leaf-bases and multicellular hairs. Mature leaves have not been observed in an attached condition with the trunk, but young fronds have been obtained in the form of terminal buds. The leaves are extremely cycad-like, but without any prominent midrib, and the venation is dichotomous.

Internally, the stem of *Cycadeoidea* shows endarch arrangement of the xylem. The pith is large, and is surrounded by a small layer of wood. Scalariform tracheids are present in the secondary xylem.

Anatomically, the leaf shows a xerophyllous structure. The epidermis is strongly cutinized, followed by one or two layers of thick-walled cells constituting the hypodermis. The mesophyll is differentiated into palisade and spongy parenchymas. Each of the mesarch bundles of the single median row is provided with a prominent bundle sheath, and connected with the dorsal face by sclerenchymatous cells. A wavy line of thick-walled cells occur below the bundles, and beneath this line is a thick zone of ill-defined sclerified cells extending upto the lower epidermis.

The flower

Flowers are sunken within the leaf-bases, and are, so far as known,

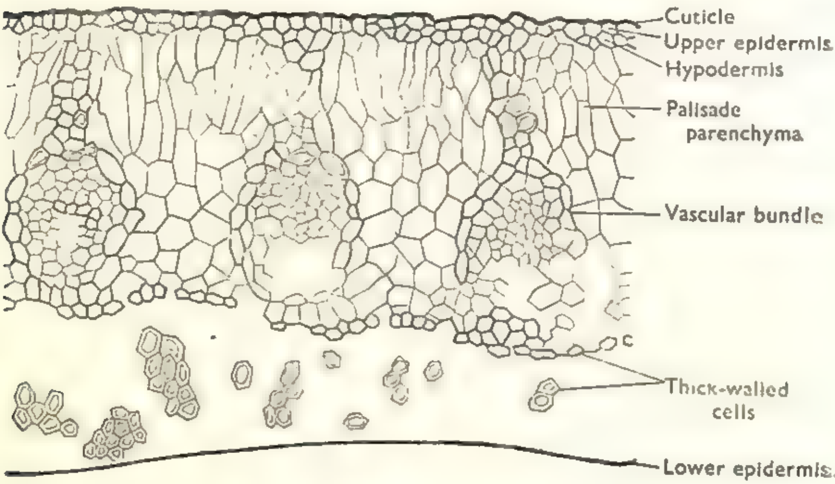


Fig. 404. *Cycadeoidea* (=*Bennettites*).
T. S. of leaf.

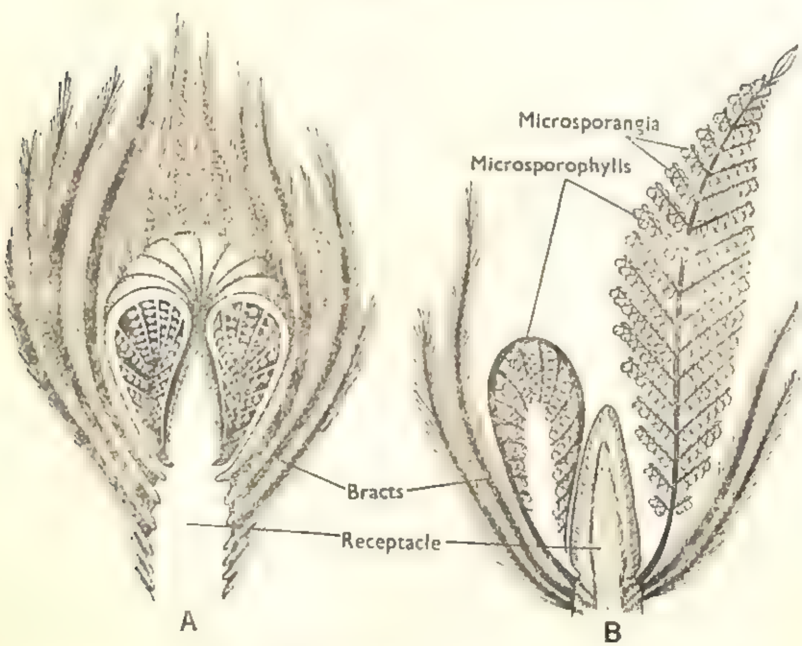


Fig. 405. *Cycadeoidea* (=*Bennettites*).
A—B, Male strobili with associated bracts. In B one of the sporophylls has been shown in an expanded condition.

bisexual. These are borne on axillary shoots. The axillary branch is expanded into a **receptacle,** which bears in the outermost region a dense cluster of bracts enclosing a number (about 10-20) of *microsporophylls* (*stamens*), and the innermost position is occupied by the *megasporophylls* (*carpels*), which are intermingled with interseminal scales. The whole structure resembles a flower of *Magnolia.*

Microsporophylls (or **stamens**). The microsporophylls or stamens bear two lateral rows of synangia of ordinary fern type. These are united at the base forming a sheath, and are not much advanced than the filicinean form.

Megasporophylls (or **carpels**). The megasporophylls or carpels are much more advanced than the microsporophylls or stamens. Each megasporophyll has a long, slender stalk bearing an ovule, and these lie intermingled with **interseminal scales,** which are probably nothing but sterile megasporophylls.

The **ovule** is of the cycadean type with a three-layered integument, whose inner and outer layers are fleshy, and the middle one is stony. The nucellus is free from the integument. The embryo is large, dicotyledonous, and fills the seed completely, and during its development destroys the endosperm.

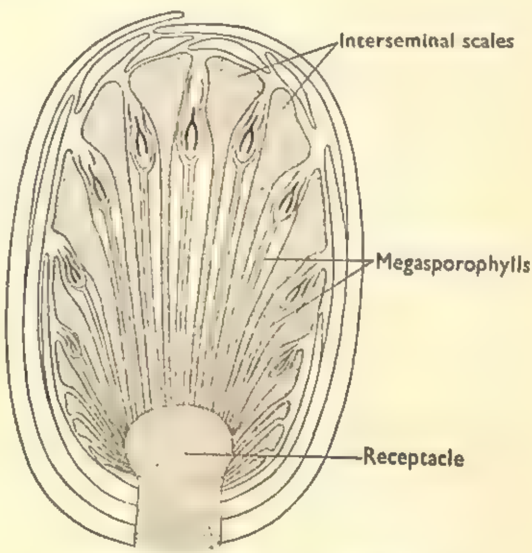


Fig. 406. *Cycadeoidea* (=*Bennettites*). L.S. of a female strobilus.

Affinity

In certain respects the Cycadeoidales shows affinities with both the Pteridosperms and the Cycadales, particularly regarding the general habit, structure of wood, mesarch leaf trace, foliage and structure of the seed. Angiospermous affinities can also be

considered by comparing their strobili with the flowers of *Magnolia*, but the similarity is only due to parallel evolution. The relationship is drawn with the ferns in having the ramentum, synangia, and direct leaf traces. Hence, this Order represents a combination of characters of Cycadofilicales, Cycadales, and Filicales along with some characters of its own.

ORDER 3. CYCADALES

The Cycadales probably appeared in the late Carboniferous from the Cycadofilicales. They became very abundant in the early Mesozoic era, and then gradually began to decline.

During the Mesozoic, the cycads were distributed all over the world, but at present they are restricted mainly to tropical and subtropical regions. Of a total number of 9 of the present-day living genera with about 90 species (65 spp. according to Schuster), 4 are western and 5 are oriental. Of the 4 western cycads, *Microcycas* is found only in Cuba, *Dioon* and *Ceratozamia* in Mexico alone, while *Zamia* occurs in both these places. The oriental genera, with the exception of only one, are also strictly endemic. *Stangeria* and *Encephalartos* occur in South Africa. *Bowenia* and *Macrozamia* are restricted to Australia, while *Cycas*, which is abundant in Australia, is also found in India, China, Japan, and Polynesia. One species of Cycas (*Cycas madagascariensis*) is, however, reported from Madagascar.

Plants woody, usually branched and dioecious; leaves bipinnate compound; sporophylls generally borne in cones (but not in the case of the megasporophylls of *Cycas*); microsporophylls bearing sporangia in groups of sori on the under surface; spermatozoids multiflagellate, motile and 2 in number; megasporophylls usually bearing one to several erect, sessile, naked ovules; embryo in a ripe seed with generally two cotyledons, and attached to a long much-coiled suspensor; stems with large pith, little wood, and thick cortex; true vessels absent. It includes only one family, Cycadaceae.

CYCAS

(Fam. CYCADACEAE)

Cycas is the most prominent genus of the eastern hemisphere. According to Hooker, there are 6 species of *Cycas* growing in India,

viz., *C. circinalis*, *C. rumphii*, *C. pectinata*, *C. siamensis*, *C. beddomeii*, and *C. revoluta*. They are usually cultivated in gardens as ornamental plants, and their leaves are extensively used for decorating purposes.

Fig. 407. A *Cycas*.

The sporophyte

The vegetative body of the sporophyte externally resembles a palm tree. The stem is typically unbranched, short, thick, cylindrical and more or less columnar, covered by an armour of persistent leaf-bases, and bearing a crown of leaves.

Fig. 408. *Cycas*.
A group of root tubercles.

Leaves are pinnate, tough, leathery, large (sometimes upto 3 metres in length), spirally arranged round the free growing apex of the stem, and show circinate ptyxis characteristic of ferns. Each leaflet has only one midrib without branches. The primary root elongates as a strong tap root with scanty branches, but numerous secondary roots are present. These secondary roots, near the surface of the ground, branch profusely and dichotomously forming coralloid masses, known as **root tubercles***.

* Root tubercles are formed due to the entrance and subsequent multiplication of 'bacterioids' from the soil causing considerable enlargement of the intercellular spaces and disorganization of some of the cells. Algae (*Anabaena*, possibly *Nostoc* also) soon occupy these spaces and their multiplication still further enlarges the size of these cavities. These tubercles possibly serve both in aeration as well as in assimilation.

A cross section of the stem shows a large pith, a comparatively thin vascular cylinder with conjoint, collateral, open and endarch bundles, and a very thick cortex showing numerous leaf-traces (**girdles**), limited externally by an epidermis. Numerous canals filled with mucilage also occur in the cortex and in the pith, and

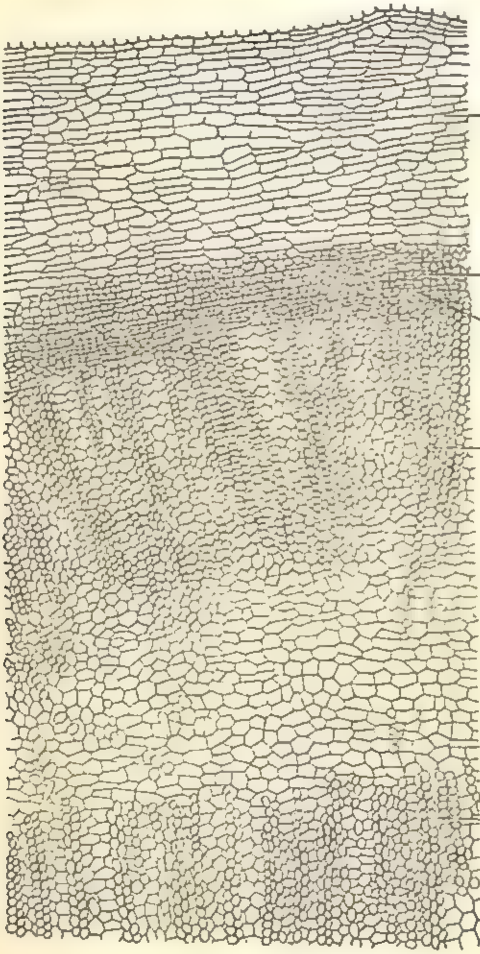


Fig. 409. *Cycas.*
T.S. of a two-year-old stem.

these are connected with one another through leaf-gaps forming a network. The primary cambium is short-lived, and a succession of secondary cambiums is formed in the cortex producing concentric series of vascular cylinders. The first cortical cambium produces

a prominent secondary vascular cylinder, the second cambium produces much narrower ones with widely separated vascular bundles, and as this process is continued the constructive power of the successive cambium layers is greatly reduced, which ultimately form isolated patches of smaller vascular bundles here and there at the periphery. These secondary cortical bundles are concentric.

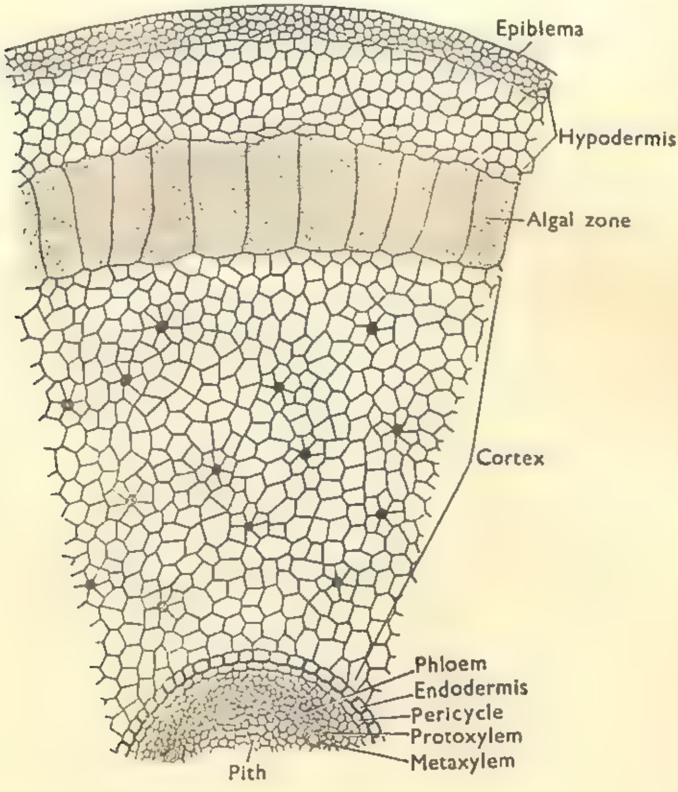


Fig. 410. *Cycas*.
T.S. of a root tubercle.

The root is usually tetrach and the secondary growth begins early but in an irregular fashion.

In a cross section of the petiole, numerous collateral and open vascular bundles are found to be present in a convoluted arc. The xylem of each bundle lies on the upper face with phloem below, and the former is composed of an endarch protoxylem with both

centripetal and centrifugal masses of xylem, which are apparently secondary in origin (Legoc, 1914).

A cross section of the leaf shows strongly cutinized epidermis on both sides of it and with deeply sunken stomata only on the under surface. Below the upper epidermis there is a hypodermis, consisting of a few layers of thick-walled cells, and this tissue gives a tough and leathery texture to the leaf. The mesophyll tissue is

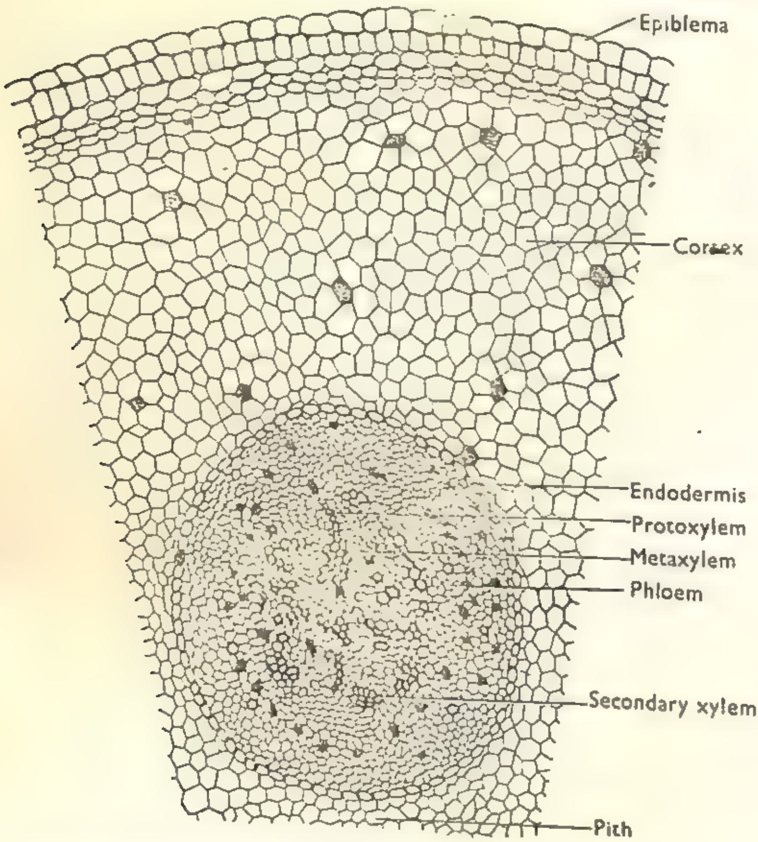


Fig. 411. *Cycas*
T.S. of a root showing the beginning of the formation of secondary xylem.

differentiated into an upper palisade and a lower spongy parenchyma, full of chloroplasts, and these two tissues are separated by colourless, elongated cells forming the **transfusion tissue,** which runs parallel to the leaf-surface. The vascular bundle is usually mesarch.

Cycas is strictly dioecious and heterosporous, the micro- and mega-sporophylls being borne on different plants. In this case, the

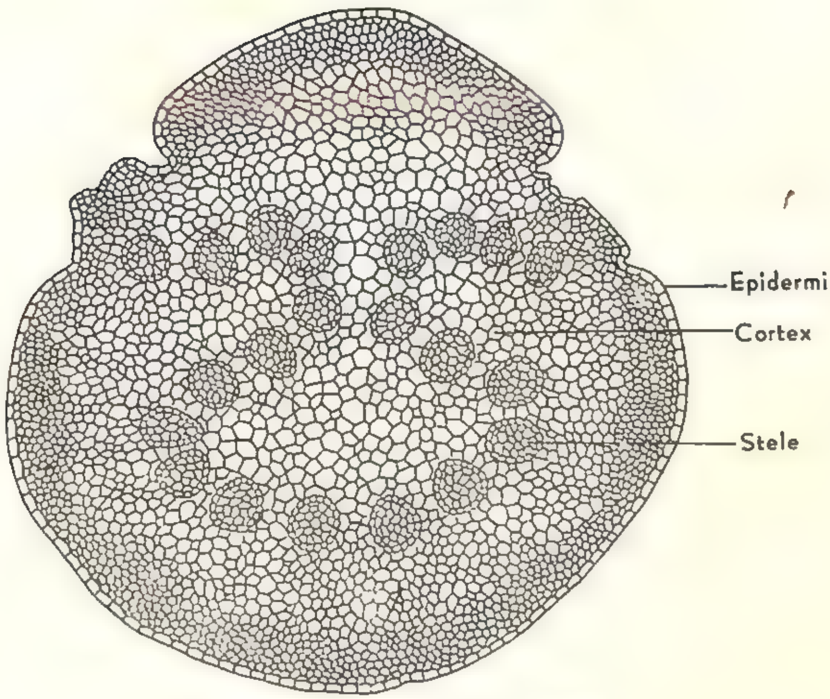


Fig. 412. *Cycas*. T.S. of the petiole.

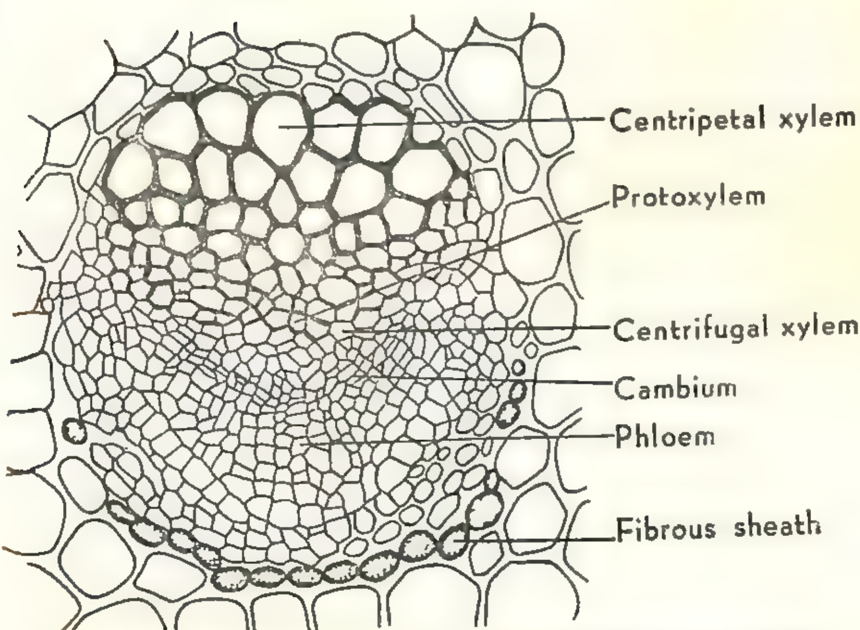


Fig. 413. *Cycas*. A single vascular bundle from Fig. 412 magnified.

around the terminal vegetative bud of the shoot axis. The megasporophylls, in some cases bear considerable resemblance to foliage leaves (*e.g.*, *C. revoluta*, *C. circinalis*, etc.), are devoid of chlorophyll, and covered with short brownish hairs. Several **ovules** or **megasporangia**, sometimes only two (*C. siamensis*), are borne on the margins of the megasporophyll. In a species of *Cycas* (*C. circinalis*) the ovules are the largest, measuring about 6×4 cm., and in some cases they are densely hairy (*C. revoluta*).

The ovule consists of a **nucellus** surrounded by a single massive integument which develops a testa of three layers: an outer fleshy, a middle stony, and an

Fig. 417. *Cycas*.
A megasporophyll with ovules.

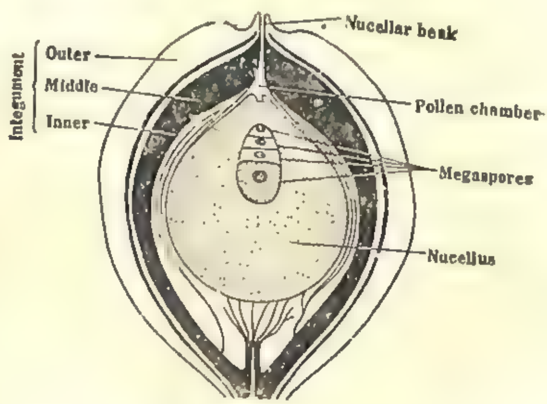


Fig. 418. *Cycas*.
Structure of an ovule at the stage of formation of linear tetrad of megaspores (in median l.s.).

inner fleshy layer. The outer fleshy layer, in a ripe seed, becomes characteristically coloured, and the inner fleshy one usually becomes thin and membraneous. The nucellus is fused with the thick integument for most part of its length, except at the apical region, where it forms a beak-like structure, called the **nucellar beak.**, which projects into the micropyle. Within the nucellar beak develops a conspicuous chamber, called the **pollen chamber,** in which the pollen grains are collected. The vascular supply

of the ovule is divided into two sets, the outer set enters the outer fleshy layer, and the inner set traverses the inner fleshy layer, just within the stony coat, and continues beyond the free portion of the nucellus. Deep within the tissue of the nucellus a **spore mother-cell** soon becomes differentiated, which by reduction division, forms a linear tetrad of four **megaspores** or **embryosacs,** of which the innermost one is functional, while the others disorganize.

The gametophytes

Male gametophyte. The microspore, the first cell of the male

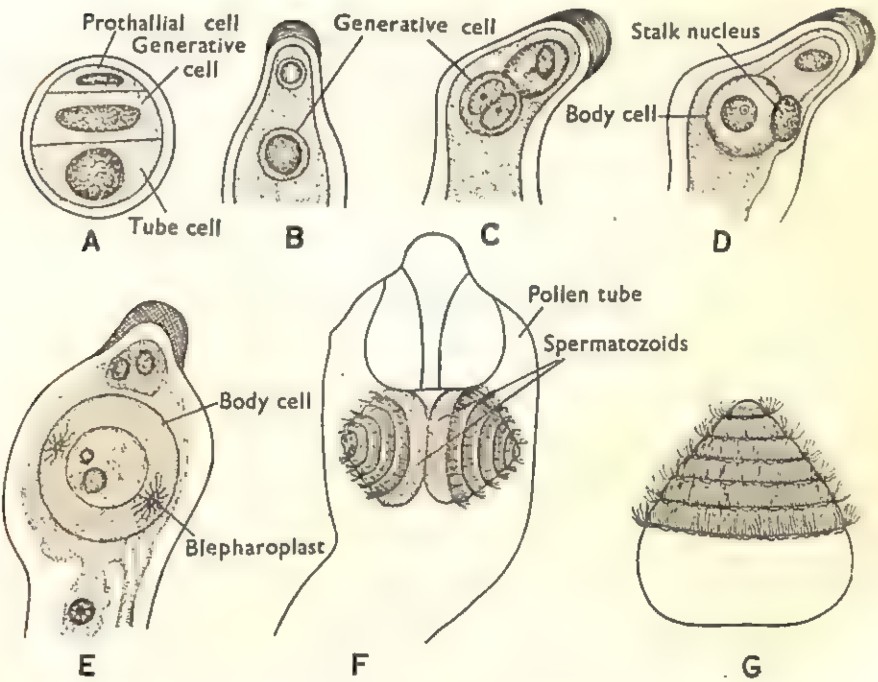


Fig. 419. *Cycas*.
A—F, Successive stages in the development of the male gametophyte;
G, A mature spermatozoid.

gametophyte, has two coats: the *exine* and the *intine*. It germinates while still within the microsporangium ; its nucleus divides and two unequal cells are formed, a small persistent **prothallial cell** or

vegetative cell, and a large cell, the **antheridial initial.** The larger cell in its turn, divides again into two unequal cells, one, a small cell closely in contact with the prothallial cell, is the **generative cell,** and the other larger cell is the **tube cell.** It is at this three-celled condition the microspores or pollen grains are discharged from the microsporangium, and are disseminated by wind. It has been accepted that *Cycas* is wind-pollinated. The three-celled microspores are carried by the wind to the ovules of the neighbouring female plants. They are caught by a mucilagenous secretion from the micropyle, and as the fluid dries up, they are sucked into the pollen chamber. The tube cell elongates and penetrates the tissue of the nucellus forming the **pollen tube,** and the tube nucleus passes into it. The pollen tube often branches, and always functions as an absorptive organ. The generative cell then divides into a **stalk cell** and a **body cell.** The former is functionless, but the latter again undergoes division producing two **spermatozoid mother-cells,** in each of which a large spirally coiled, multiflagellate **spermatozoid** is produced. These spermatozoids are remarkably large, larger than any known in other plants and animals, and are easily visible to the naked eye.

Female gametophyte. The megaspore is the first cell of the female gametophyte. It germinates within the megasporangium (or ovule), and is never shed, but is retained within it. The development of the gametophyte can be broadly divided into five stages: (1) the megaspore enlarges, its nucleus divides freely forming a variable number of free nuclei distributed in its general mass of cytoplasm; (2) due to the development of a large central vacuole, all the nuclei are placed at the periphery of the megaspore; (3) free nuclear division continues; (4) a peripheral tissue is gradually developed by the formation of cell walls separating the free nuclei; (5) this process is continued, and the tissue grows centripetally until it fills up the cavity of the megaspore. This gametophytic tissue, which is developed before fertilization, is known as the **endosperm,** which, at maturity, contains abundant starch grains. It consists of two regions: (*a*) a region of large cells near the base performing nutritive function, and (*b*) a region of small cells near the micropylar region. Within the latter region develops a variable number of **archegonia** (2-8 in *C. revoluta*). Any superficial cell of the gametophyte may become an **archegonium initial,** which divides periclinally into an outer **primary**

neck cell, and an inner **central cell.** The primary neck cell divides vertically to form two *neck cells,* while the central cell enlarges remarkably and gradually becomes surrounded by a special jacket of nutritive cells, known as the **archegonial jacket.** The nucleus of the central cell finally divides to form a *ventral nucleus,* and an *egg nucleus,* and there is no wall in between the two. The absence of

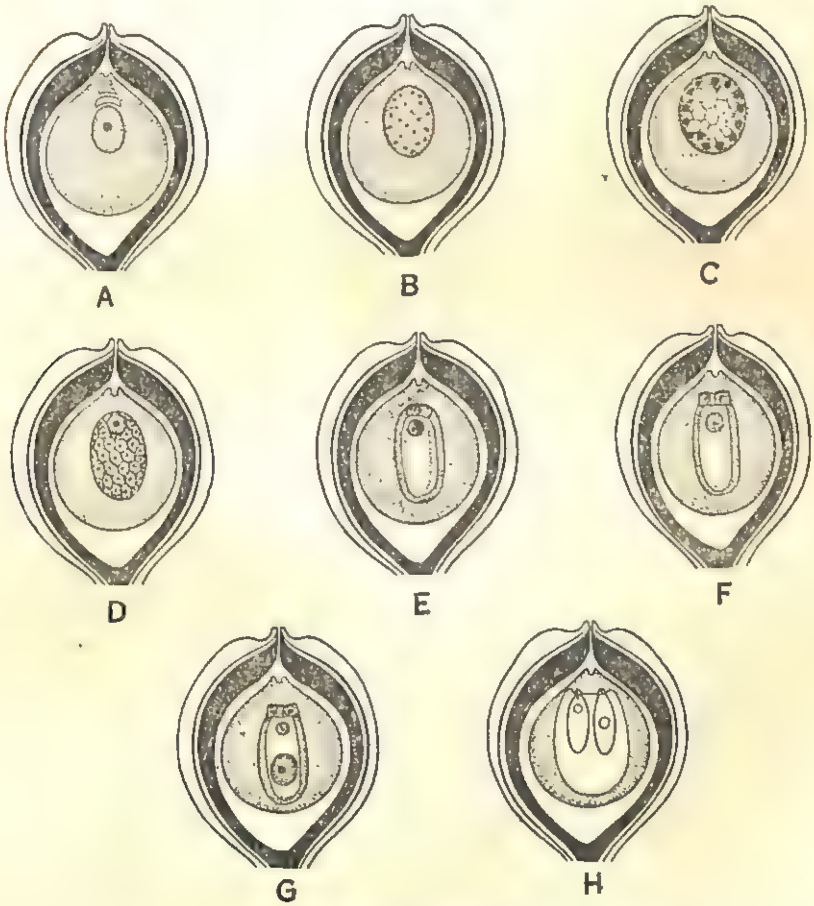


Fig. 420. *Cycas.*
A—H, Successive stages in the development of the female gametophyte.

such a wall is regarded as an advanced character. Around the latter an *oosphere* is gradually differentiated. The ventral nucleus soon disorganizes. The oosphere and its nucleus have been described as the largest among plants, and can be detected by the

unaided eye. During the development of the archegonia at the micropylar surface of the gametophyte, its neighbouring cells continue to grow upwards, so that the archegonia are left in a shallow depression, known as the **archegonial chamber.**

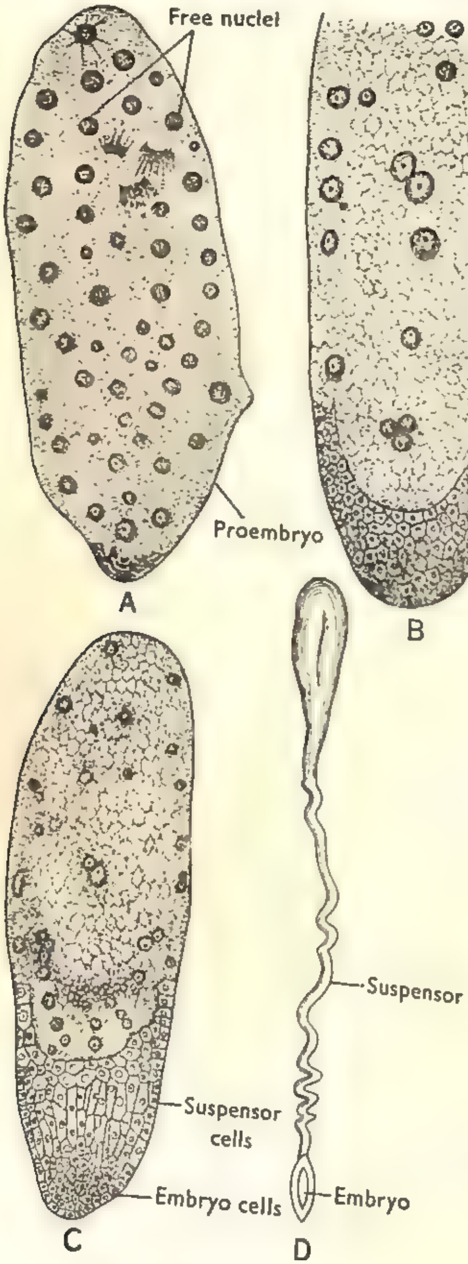


Fig. 421. *Cycas.*
A—C, Successive stages in the development of the embryo of a cycad (*Zamia*); D, A mature embryo.

After penetrating the nucellus the pollen tube bursts, when the spermatozoids are set free in the archegonial chamber. The spermatozoids then make their way into the archegonium, and one of them fertilizes the oosphere. The fertilized oosphere surrounds itself by a wall, and forms an **oospore.**

The new sporophyte

After fertilization the oospore enlarges, its nucleus by free cell-formation produces as many as 256 or probably more (*C. revoluta*) nuclei, distributed through the cyto-

plasm of the oospore. A large central vacuole soon appears (*C. circinalis*), followed by the formation of a peripheral tissue. This tissue is the **proembryo.** Further details are not known in *Cycas.* But in another genus, *Zamia*, the development has been fairly worked out. In *Zamia* the proembryo is formed only at the lower end of the developing oospore. The cells below the tip-cells of this proembryo elongate remarkably, and ultimately form a long, coiled, flexuous and massive filamentous structure, called the **suspensor,** which forces the tip-cells out of the archegonium into the nutritive gametophytic tissue (endosperm). From the tip-cells a dicotyledonous embryo is produced. The embryo and the endosperm remain within the three-layered testa, and the ovule is gradually transformed into a seed. The seed, on germination, gives rise to a new seedling sporophyte, and the mode of germination is hypogeal.

ORDER 4. CORDAITALES

The Cordaitales appeared in the Devonian period or perhaps in Silurian, reached their climax in the Carboniferous, and finally disappeared in the Permian, although some believe that they continued upto the Triassic. Fossil remains are distributed over North America, some parts of South America, Great Britain, France, Russia, India, China, Australia and Africa.

Prof. Sahni has placed this Order in **Stachyospermae,** because the ovules are stem-borne. The stele is cylindrical, and leaf traces are conspicuous.

The Order is usually divided into *three* families: **Pityeae, Cordaiteae,** and **Poroxyleae.** Of the three families, the best known as well as most extensively studied one is the Cordaiteae.

A brief account of each of the families is given below :

1. Pityeae. The important genera belonging to this family are *Pitys*, *Archaeopitys* and *Callixylon.* The foliage structure is only known in case of *Pitys dayi*, which is fleshy and about 4-6 mm. in diameter. There is no definite leaf gap present. The structure of the stem is known. A cross section of the stem of *Callixylon* shows a parenchymatous pith, mesarch primary wood, compact secondary wood with characteristically alternately pitted tracheids, feeble growth rings and uni- to multi-seriate rays. A group of pits (occurring on the radial walls) alternating with an

unpitted area in a regular pattern is a unique feature of this wood only. No fructification is known as yet.

2. Cordaiteae. The important genus is *Cordaites*, which is an assemblage of different form genera. For details—see below.

3. Poroxyleae. This family is very restricted in its distribution and consists of only one genus, *Poroxylon*, with two species. The structure of the stem comprises of a large pith, surrounded by a primary exarch wood. The secondary wood is loose, and the leaves are strap-shaped. The seed is known as *Rhabdocarpus*.

The common Indian Cordaitales are *Neoggerathiopsis hislopi*, *N. stolickzames*, *Euryphyllum willianum*, *Samaropsis ranigangensis*, *S. milloii*, *Squamaforma integerrima*, *S. formalacerata*, *Cordaicarpus indicus*, *Dadoxylon indicum*, etc.

CORDAITES

(Fam. CORDAITEAE)

Fig. 422. *Cordaites*.

Cordaites is the most important genus in the family Cordaiteae. The genus is an assemblage of different form genera. The stem genera are termed as *Mesoxylon*, *Dadoxylon**, etc., the root as *Amyelon*, the inflorescence as *Cordaianthus*, the seed as *Samaropsis*, *Cordaicarpus*, etc.

The sporophyte

The stem is tall and slender, branching only at the top, and bearing long, slender, spirally arranged leaves. The leaves are linear, lanceolate to spathulate in shape, and there is no midrib. The veins are arranged in a parallel fashion.

* The important species of Indian *Dadoxylon* are *D. indicum*, *D. bengalense* and *D. resinosum* from the Lower Gondwana.

The structure of the stem shows a large parenchymatous pith, which is partly septate due to the formation of diaphragms, as is found in the modern *Juglans*. The primary wood is small and endarch. The secondary wood forms a thick layer; tracheids are pitted. Pits are uni-, di-, or tri-seriate; the rays are simple. Growth rings are rare.

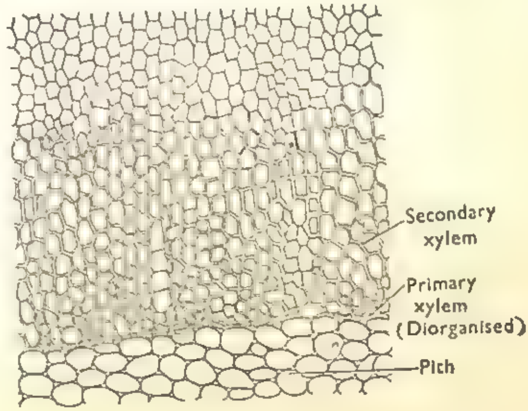


Fig. 423. *Cordaites*. T.S. of the stem (in part).

The central cylinder of the root is a di-, tri-, or tetrarch protostele, and is surrounded by secondary wood. The periderm is very well-developed.

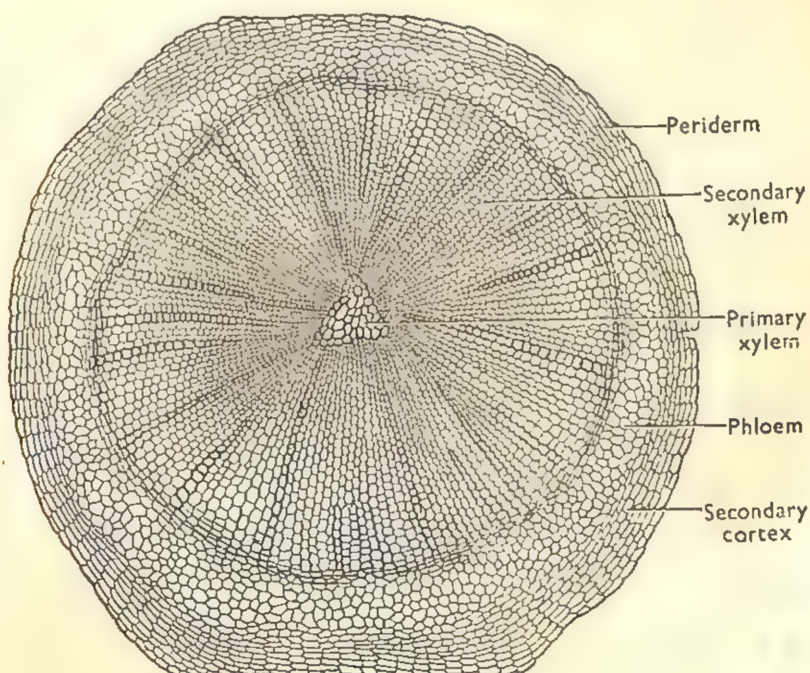


Fig. 424. *Cordaites*, T.S. of the root.

Internally, the leaf shows xerophytic characters, and possesses a thick cuticle. The upper epidermis is highly cuticularized, below which there is a thin hypodermis, composed of one or two layers of thick-walled cells. The mesophyll is mainly composed of palisade parenchyma cells; the cells towards the lower epidermis are angular, closely set, and without any intercellular spaces. The vascular bundles are arranged in a parallel series; each bundle is surrounded by a sheath, and is connected with the hypodermis by means of a band of thick-walled cells. Though the lower epidermis is not found in a very well-state of preservation, the guard cells are noted to be provided with 4-6 subsidiary cells.

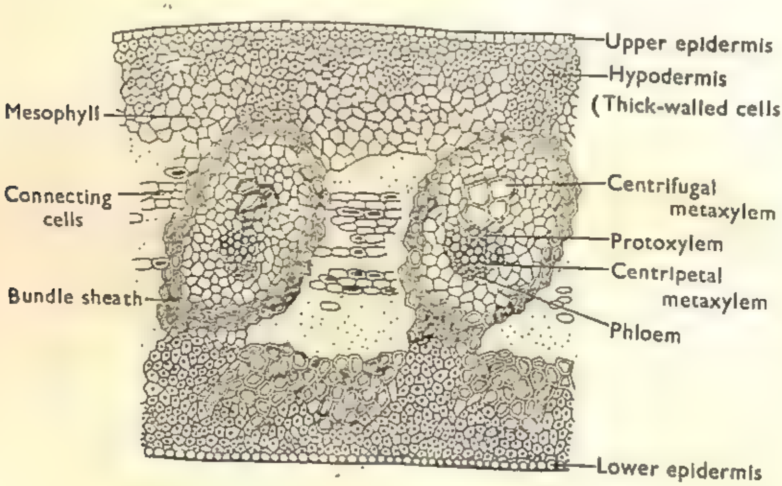


Fig. 425. *Cordaites.*
T.S. of the leaf.

Cordaites may be either monoecious or dioecious, and bear small monosporangiate strobili on stalks, the male ones being more numerous than the female ones.

Staminate (or **male**) **strobilus.** It consists of a short axis bearing spirally-arranged, sterile bracts, and fertile **microsporophylls,** each of the latter supporting a number of **microsporangia** or **pollen sacs.** The microspores or pollen grains are globose, and the exine is inflated forming a big air-containing sac, which, with the exception of a small area at one corner of the pollen grain, can be regarded essentially as an antheridium, comparable to that

as found in the present day gymnosperms, and probably gave rise to the pollen tube.

Pistillate (or **female**) **strobilus.** Like the male one, it also bears a stout axis, bracts and a few (usually 1-4) **megasporophylls.** The ovules are borne on slender stalks, and in fully ripened specimens, the seed completely outgrows the bracts. The general plan of construction of the ovule is of the cycadean type. The nucellus is practically free from the three-layered, solitary integument, excepting at the base; the nucellar beak projects into the micropyle. The pollen chamber is conspicuous.

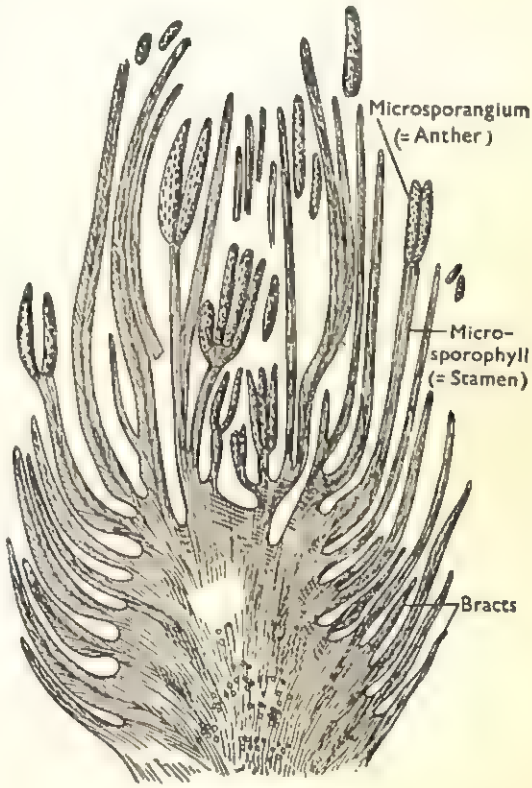


Fig. 426. *Cordaites.* L.S. of the male strobilus.

The gametophytes

Male gametophyte. Soon after the shedding of the winged pollen grain, a large number of cells develop within its body. The nature of the cells is not properly known.

Female gametophyte. There are two archegonia present and the structure is an elongated one.

In all probability the fertilization was effected with the help of motile sperms.

Seed. The seed is flattened and winged.

Embryo. Regarding the embryo nothing is practically known, excepting the recent findings of Darrah from the coal balls of Iowa.

Affinity

This Order exhibits a combination of characters of the Pteridosperms, Cycadeoidales, Cycadales, Ginkgoales, and Coniferales, together with peculiarities of its own. As to the structure of the seed, large pollen chamber and two sets of vascular strands, it resembles the Pteridosperms. It shows an affinity with the Cycadeoidales in the general organization of strobili and reduction of bracts, but it differs from the latter in its monosporangiate nature.

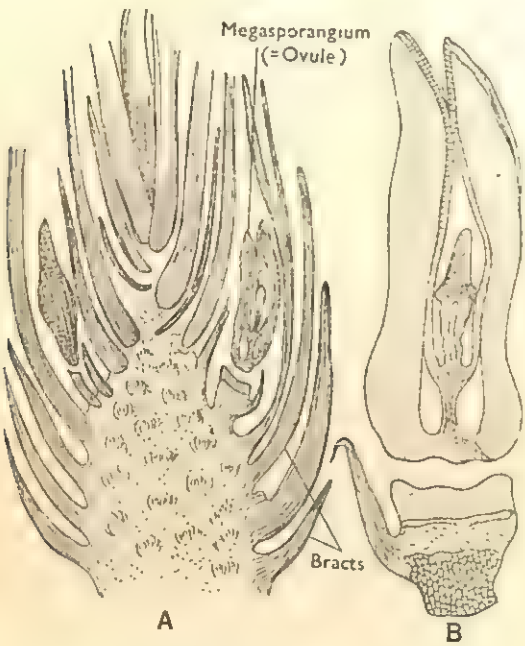


Fig. 427. *Cordaites.*
A, L.S. of the ovulate strobilus; B, L.S. of a mature ovule.

Its resemblances with the Cycadales is also very prominent, because of the large pith, the abundance of sclerenchyma in the leaf, the general structure of seed, and the probable presence of swimming sperms. The anatomical evidence, general habit, leaf structure, and nucellar beak suggest its affinity with the Ginkgoales. The resemblance between Cordaitales and Conifers in the lofty habit, and the inflorescence (*Cordaianthus*) can be homologized to the abietinean cone.

ORDER 5. GINKGOALES

The Ginkgoales appeared in the Permian or probably in the Carboniferous, reached their climax in the Jurassic, and began to decline before the Jurassic came to an end. At present they are found growing in an apparently wild condition in some mountainous places of western China. The majority of the plants are cultivated as temple trees in China and Japan. There is only one living genus

*Ginkgo** under the Order with one species *biloba*, and the plant is included under the single family **Ginkgoaceae.**

GINKGO

(Fam. GINKGOACEAE)

The sporophyte

The plant, popularly known as 'maiden hair tree', is a beautiful tree of pyramidal habit, reaching a height of about 30 metres, and with a girth of more than 1 metre. In case of an old tree, the outline may be rounded at the top. There are two kinds of branches: **long shoot** and **dwarf shoot** or **spur.** The branches, in addition to bearing normal long-pointed leaves, possess scale leaves. On the long shoot, the leaves are spirally-arranged, whereas on the spur, due to the suppression of the internodes, the leaves appear to be whorled. Furthermore, the scattered leaves are broadly fan-shaped with a repand margin, and are provided with a deep apical notch, giving the blade its characteristic bilobed appearance. On the other hand, the leaves on the spur shoot are, as a rule, undivided. The venation is rather characteristic. The two main strands from the petiole enter into the lamina, and by forking repeatedly give rise to a symmetrical dichotomous venation. The leaves are deciduous, and fall off in winter. It is interesting to note, however, that in fact, no rigid line of demarcation can be drawn in between the two kinds of lateral shoots, as, in some cases, spurs may grow out into long shoots.

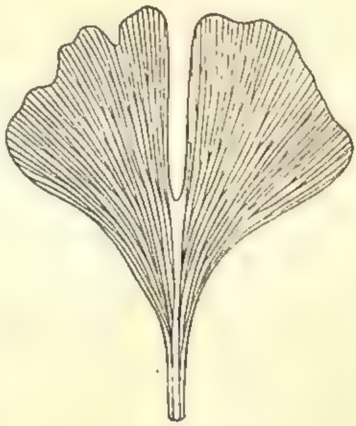


Fig. 428. *Ginkgo*. A single leaf.

Internally, the stem resembles the structure of that of the *Pinus*. Particularly, the wood structure can be regarded as strictly abietinean. The protoxylem is composed of spiral elements, and the metaxylem of bordered pitted ones, the pits occurring irregularly either in a single row or in two rows. Bars of Sanio between the pits,

*The proper spelling should be *Ginkyo*.

as well as trabeculae crossing the interior of the tracheids, are noted in the secondary wood. The wood of the long shoot is harder than

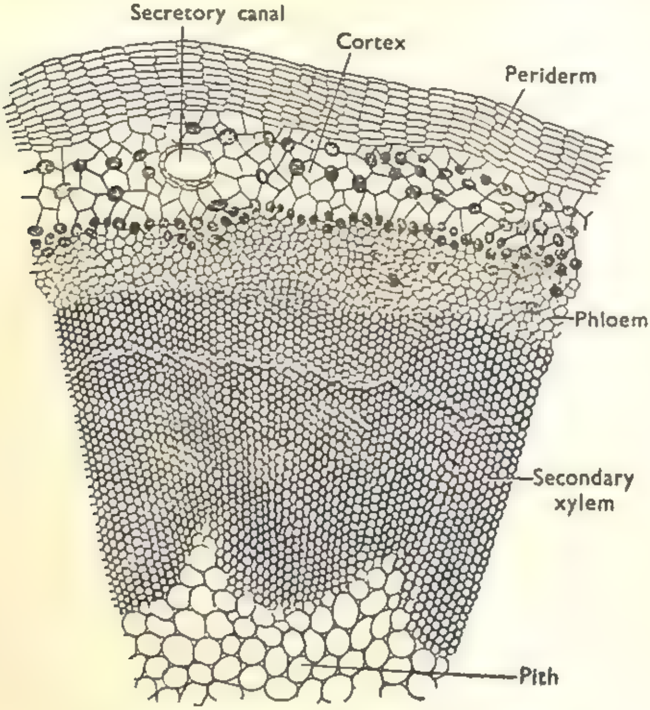


Fig. 429. *Ginkgo*. T.S. of a two-year-old stem.

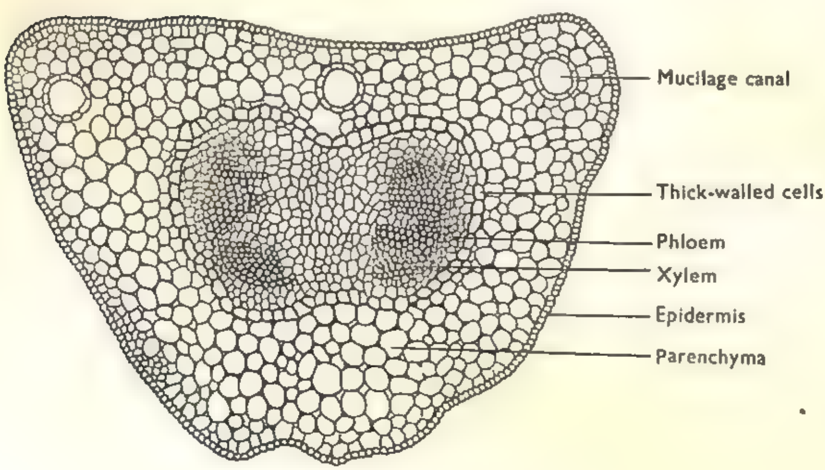


Fig. 430. *Ginkgo*. T.S. of the petiole.

that of the dwarf one, and the mucilage canals are far more numerous in the latter than in the former. The annual rings, though not so prominent as in the *Pinus*, can be clearly marked out. In both the shoots the periderm develops to a considerable extent.

Normally, the root possesses a diarch cylinder, but the same becomes triarch, when the embryo contains three cotyledons. The mature root possesses annual rings like a mature stem.

In the petiole there is a double leaf trace, each one being composed of a collateral bundle, and surrounded by a sheath made up of thick-walled cells. The bundles exhibit secondary growth.

In a cross section of the leaf, the upper continuous epidermal layer and the lower discontinuous one, interrupted at intervals by the stomata, can be clearly differentiated out. It is interesting to note that the mesophyll, in the case of leaves on the long shoots

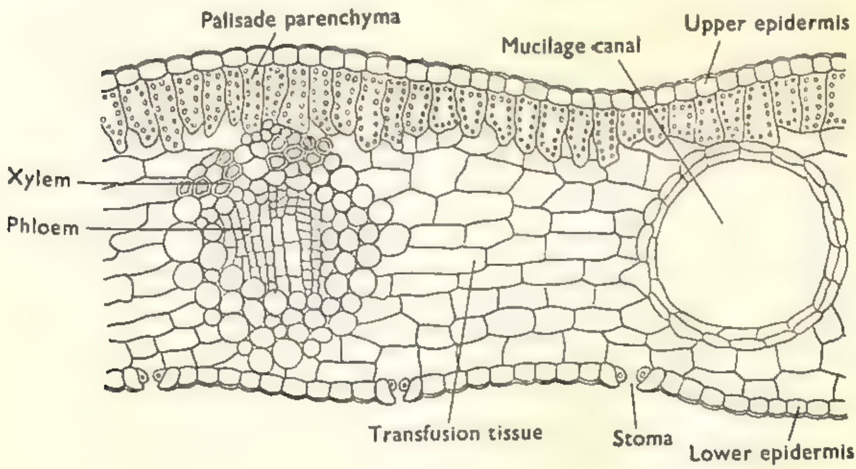


Fig. 431. *Ginkgo*.
T.S. of the leaf.

only, is differentiated into upper palisade and lower spongy parenchymas. On the other hand, the mesophyll of the spur leaves is almost uniform, with the exception that in the middle region the loosely-arranged cells are placed somewhat parallel to the surface of the leaf in the fashion of the **transfusion tissue** of *Cycas*. Prominent mucilage canals are present in the mesophyll. The vascular bundles are collateral and closed.

Ginkgo is a dioecious plant, the male and female strobili being borne upon entirely different trees.

Staminate (or **male**) **strobilus.** An entire male strobilus looks very much like a small catkin. The strobili are borne in clusters in the axils of leaves developed on the spur shoots. Each strobilus consists of a slender axis, which bears a number of spirally-arranged, ebracteate *sporophylls*. A sporophyll bears normally two, hanging *microsporangia* at its tip, surmounted by a sterile **hump,** but occasionally 3-4 sporangia may be found. According to some, the hump may be regarded as a sterile microsporangium. The *microspores* or *pollen grains* are produced by reduction division of spore mother-cells. Each pollen grain is provided with two coats: the *exine* and the *intine*. The former does not cover the whole of the pollen grain, and thus, there are two little lateral **ears** resembling the wings of the pollen of *Pinus* in a miniature scale.

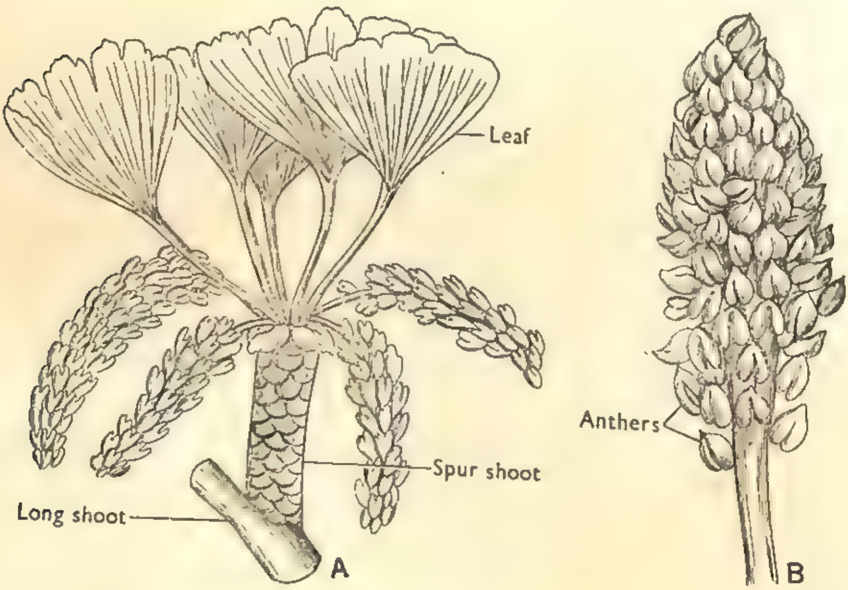


Fig. 432. *Ginkgo*.
A, A portion of the shoot bearing a number of male strobili; B, A single male strobilus (magnified).

Pistillate (or **female**) **strobilus.** Like the male strobili, the female ones also are borne in the axils of leaves or scales, developed on the spur shoots of the female trees. Each female strobilus consists of a simple stalk, which bifurcates at its tip, and each branch bears a solitary, terminal, sessile *ovule*, the lower part of which remains encircled by a fleshy, cup-like structure, known as the

collar or **ring.** The morphological nature of this collar is a much-debated point, but the majority of workers like to interpret it as a modified megasporophyll. Usually, only one of the pair of ovules attains maturity.

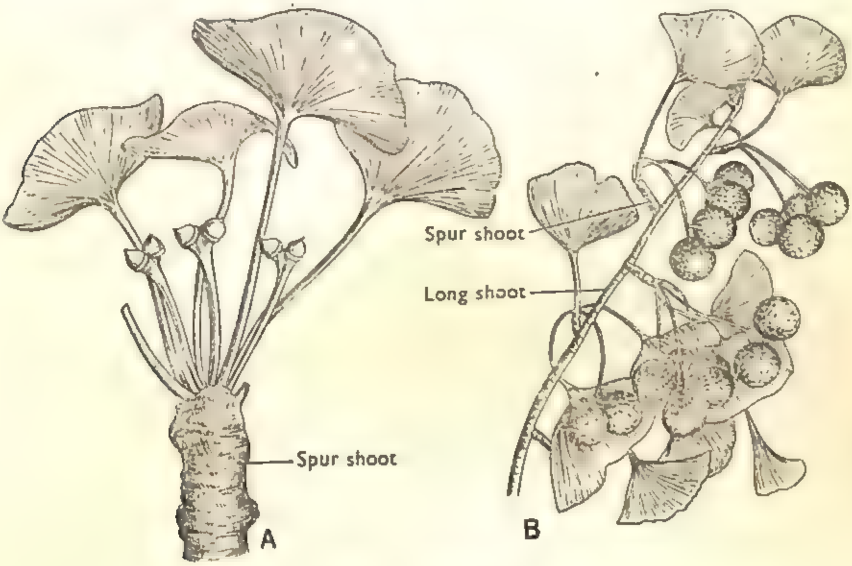


Fig. 433. *Ginkgo.*
A—B, Portions of plants bearing ovules.

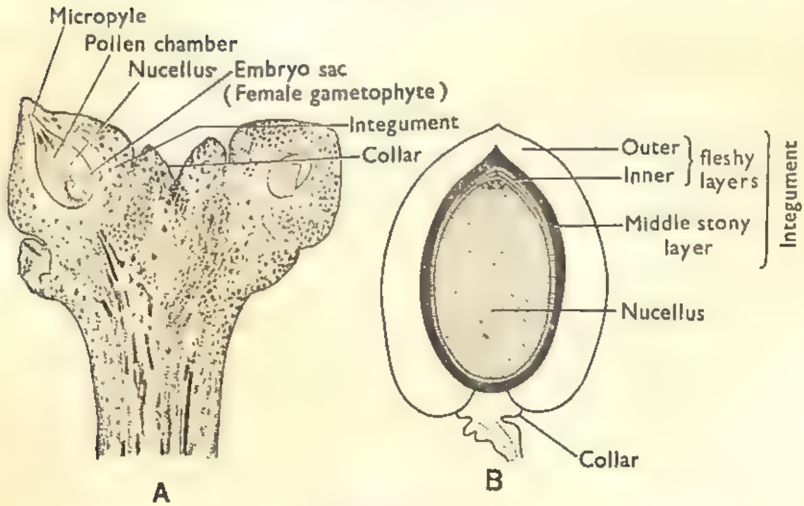


Fig. 434. *Ginkgo.*
A, Median longitudinal section through the apex of an ovuliferous axis; B, L.S. of an ovule.

The structure of the ovule is very much similar to that of *Cycas* with a striking point of difference, in the fact, that there is no vascular supply to the integument. By the breaking down of the free apex of the nucellus, a conspicuous **pollen chamber** is produced.

The gametophytes

Male gametophyte. The microspore is the first cell of the male gametophyte. It germinates while still enclosed within the microsporangium. The microspore-nucleus divides mitotically, and two highly unequal cells are produced, the lower one being known

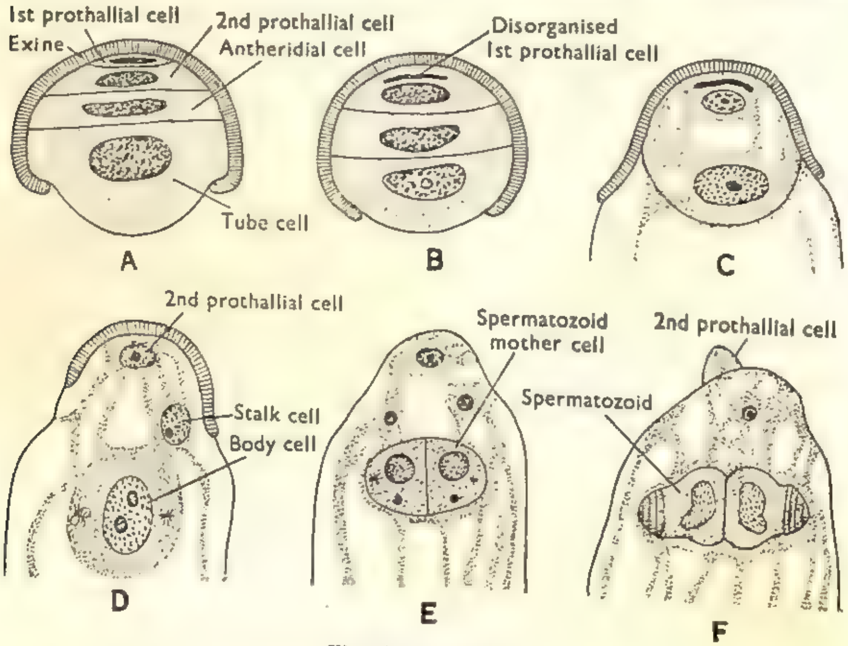


Fig. 435. *Gingko*.
A—E, Successive stages in the development of the male gametophyte; F, two spermatozoids.

as the **first prothallial** (or **vegetative**) **cell.** The larger cell undergoes a second mitotic division giving rise to a smaller cell, the **second prothallial cell,** and a larger **antheridial initial cell.** The first prothallial cell degenerates very quickly, while the second one is persistent. The antheridial initial cell then divides in its turn, and produces a **generative cell,** lying in contact with the second prothallial cell, and a **tube cell.** As in *Pinus*, the microsporangium opens by a longitudinal slit, and the pollens are liberated at this four-celled stage. The pollen grains are dispersed by

the wind, and get deposited on the open micropylar end of the ovule, where they are stuck up in the pollination drop, and subsequently brought within the pollen chamber. This constitutes the pollination in *Ginkgo*, which occurs in the beginning of May. The generative cell divides within the pollen chamber, and produces a non-functional **stalk cell,** and a **body cell.** As in *Cycas*, by the division of the body cell, two multiflagellate, swimming *sperms* are produced. Meanwhile, the tube cell has protruded out, and formed a *pollen tube*, which is more or less haustorial in nature, and it makes its way through the nucellus towards the female gametophyte.

Female gametophyte. The megaspore is the first cell of the female gametophyte. The development of the female gametophyte and that of the pollen tube start almost simultaneously. During its early stage of development, the female gametophyte is surrounded by a zone of spongy tissue which absorbs the tissue lying outside it; but, later on, it is itself used up by the developing gametophyte. The mode of development of the female gametophyte of *Ginkgo* is also like that of *Cycas* with a few interesting deviations. For instance, when the free nuclear period is coming to a close, a delicate membrane, very much distinct from the megaspore-membrane, is laid down on the outer surface of the protoplasmic layer. At the time of cell-formation, cell walls begin to be laid at right angles to this membrane. Primarily, the inner side of the innermost cell remains naked, but when the wall-formation stops, a wall is deposited on the naked face of the cell. Consequently, the innermost cells, coming from opposite directions within the developing megaspore, do not have a common wall, but each one is provided with a wall of its own, so that the female gametophyte has a plane of cleavage along the middle region. It is to be noted that chloroplasts are present in the cells of the female gametophyte (**endosperm**).

Archegonia, as usual, are developed towards the micropylar end of the endosperm. There are usually two, occasionally three, archegonia formed. Each archegonium has a two-celled *neck*, a distinct *ventral canal cell*, and an *egg cell*. But, here, instead of a cup-shaped archegonial chamber, as is found in *Cycas*, a circular trough is developed, surrounding a central mass of beak-like tissue supporting the remnant of the nucellus; this is known as the **tent-pole** structure.

Fertilization takes place in late September, *i.e.*, four months after pollination has been effected. The tip of the pollen tube, carrying the two sperms, bursts open, and the contents are discharged within the archegonial chamber. The sperm-nucleus unites with the egg-nucleus near about the centre of the egg, and brings about fertilization. The fertilized egg-cell develops into an **oospore.**

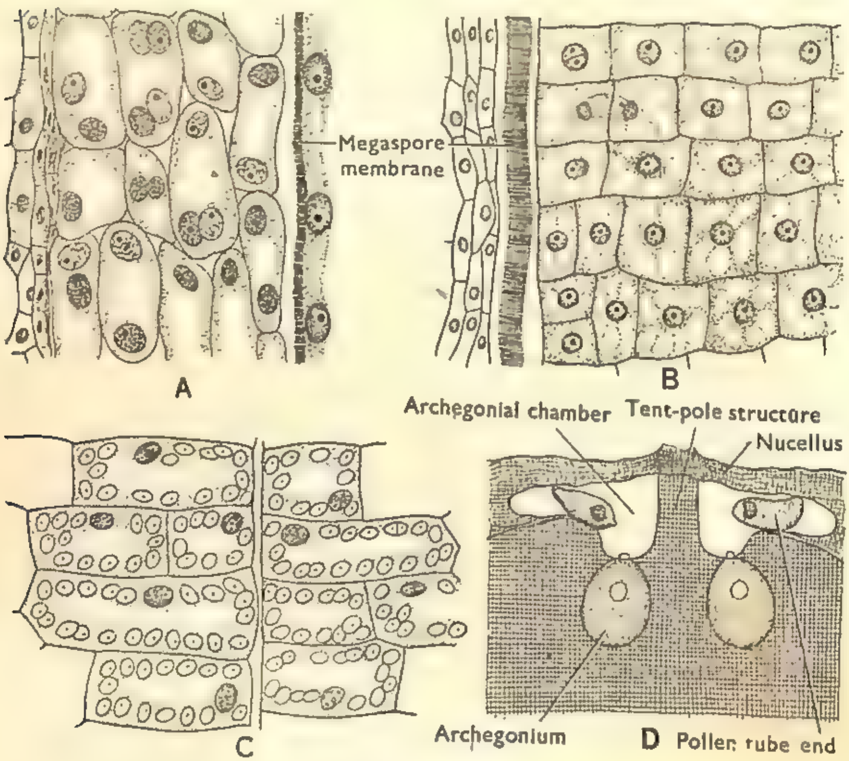


Fig. 436. *Ginkgo.*
A—C, Stages in the development of endosperm; D, Formation of the tent-pole structure.

The new sporophyte

The oospore enlarges, and a period of free nuclear division commences. The nuclei (usually 256 in number) are evenly distributed throughout the cytoplasm of the oospore. Subsequently, simultaneous wall-formation takes place, and the whole interior of the archegonium becomes filled up with cells of approximately the same size. Later on, the cells near the base become numerous and

small, from which the *embryo* is developed. On the other hand, the cells of the developing sporophyte in the neck region of the archegonium enlarge, but there is no organized suspensor formed. The embryo is typically dicotyledonous. The mode of germination of the seed is hypogeal, and a seed, on germination, gives rise to a seedling-sporophyte.

ORDER 6. CONIFERALES

The Coniferales appears to have originated in the late Carboniferous. The Order reached its climax in the Cretaceous, and is still very abundant in comparison to all other living gymnosperms. The living conifers are world-wide in their distribution. Chamberlain lists about 490 species under 39 genera, though he himself does not believe it to be a complete one of all the described genera. It is interesting to note that, unlike the cycads, many genera are common to both eastern and western hemispheres. At the same time, it is also noteworthy that while the majority of the cycads are situated south of the equator, in the case of the conifers they are in the north. There are *six* families under the Order *viz.*, (1) **Abietaceae,** (2) **Taxodiaceae,** (3) **Cupressaceae,** (4) **Araucariaceae,** (5) **Podocarpaceae,** and (6) **Taxaceae***.

PINUS

(Fam. ABIETACEAE or PINACEAE)

Pinus, the familiar pine tree, has a large number of species, which are widely distributed throughout the northern hemisphere, specially in extra-tropical regions. In India, the different species of *Pinus* are mainly restricted to the western Himalayas, while only *P. khasya* is found to be growing in the Khasia and Jaintia hills of Assam. According to Hooker, there are four species in India, which are as follows : *P. excelsa*, *P. longifolia*, *P. khasya*, and *P. gerardiana*.

The sporophyte

The plants are tall trees, which are characterized by the excurrent

*On account of some peculiar features of *Taxus*, Prof. Sahni suggests that the genus, along with *Cephalotaxus* and *Torreya*, should form a new Order Taxales, which should be equal in rank with the Coniferales.

type of branching, and fascicles of slender, needle-like, evergreen foliage leaves. The main stem is stout, cylindrical, bearing a series of wide-spreading branches, and covered by a scaly bark. At its apex there is a relatively large terminal bud. It bears two kinds of shoots: (*a*) one of unlimited growth or **long shoot,** and (*b*) the other of limited growth or **dwarf shoot**. The long shoots usually bear scale leaves, in the axils of which numerous dwarf shoots appear. There is a fascicle of two or more needle-like leaves, closely held together at the base by a circle of scales, at the apex of each dwarf shoot. The primary root-system is persistent and perennial, and consists of a large and deeply-penetrating tap root, which branches extensively. In some species the tap root may die early.

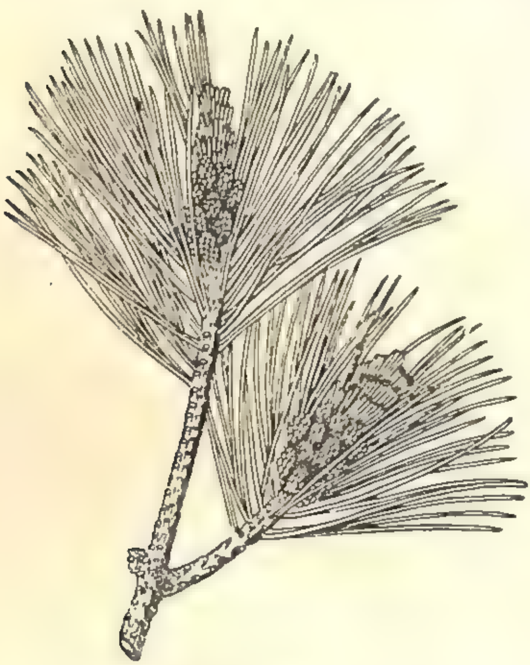


Fig. 437. *Pinus*.
Branches bearing staminate strobili.

The primary structure of a young stem in a cross section shows three distinct regions: epidermis, cortex and stele. At the centre of the stele is a parenchymatous pith, which is surrounded by a ring of vascular bundles, separated from one another by primary medullary rays. Each vascular bundle is conjoint, collateral, and open. The xylem contains tracheids, and not trachae or true vessels, characteristic of the xylem of an angiosperm. The phloem consists of sieve-tubes, and phloem parenchyma. In between xylem and phloem there is a strip of cambium. The cortex is made up of parenchyma, frequently with chloroplasts, and is traversed by longitudinal resin canals (ducts). On the outside there is an epidermis with heavily cutinized outer wall. During secondary growth, secondary xylem

and phloem are produced by the cambial activity, as in the dicotyledons, and conspicuous annual rings are gradually developed. Secondary medullary rays are formed in the usual way. Resin canals also appear in the secondary xylem. At the time of cambial activity within the stele, a complete ring of cork cambium appears in the hypodermal region of the cortex, which eventually gives rise to the periderm. Later on, successive layers of cork cambium appear deeper and deeper in the cortex, and finally in the outer part of the phloem. In this way a thick protective bark develops on the outside of the stem of *Pinus*.

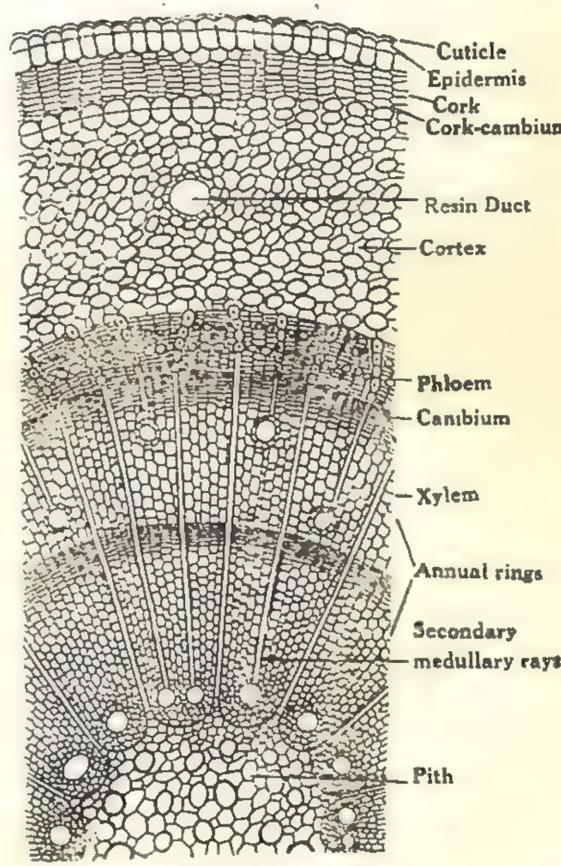


Fig. 438. *Pinus*.
Part of a cross section of a two-year-old stem.

A cross section from the middle of a leaf of the current year shows from outside inwards a single-layered epidermis composed of thick-walled cells with a heavy cuticle, the lumen of each cell being often nearly obliterated. The hypodermis is sclerenchymatous, with fine pits on the lignified walls; it is several cells deep, specially at the ridges. A few stomata are noted, each stoma interrupting the epidermis and the hypodermis, and opening into a respiratory cavity in the mesophyll, which consists of several layers of large, polygonal, thin-walled, parenchyma cells containing cytoplasm, nucleus and abundant chloroplasts; their cellulose walls are infolded to form peculiar

projections into the cell cavities. A few resin ducts, lined by a thin epithelial layer and surrounded by a sheath of sclerenchyma, are also present in the mesophyll. There are two vascular bundles, each one having its xylem towards the upper side of the leaf, and its phloem facing the lower side, which is usually more or less convex; the bundles are embedded in a many-layered ground tissue, the pericycle, which is surrounded by an endodermis, consisting of a single layer of parenchyma clearly separating the central region from the mesophyll. The pericycle consists of two kinds of parenchyma

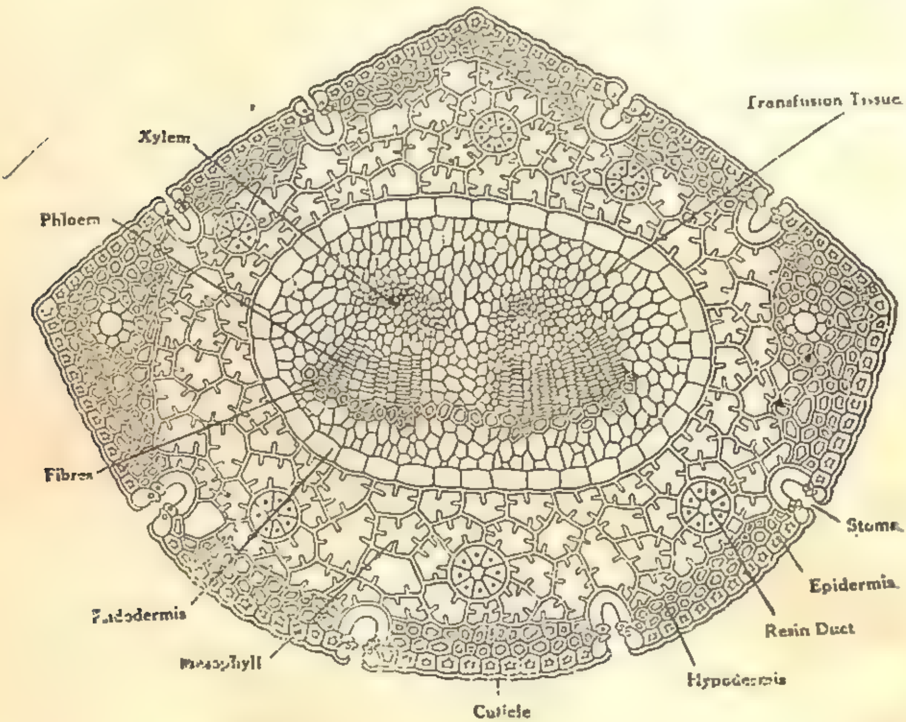


Fig. 439. *Pinus*.
Cross section of a needle.

cells, termed collectively the **transfusion tissue,** and an irregular band of sclerenchyma lying across and below the phloem of each bundle, and connecting them. The transfusion tissue consists of (*a*) **albuminous cells,** that is, cells with cellulose walls, containing protein and starch, and serving for the translocation of prepared foods from the mesophyll to the phloem, and (*b*) **tracheidal cells,** which are empty dead cells with lignified walls possessing bordered

pits, functioning as channels for water and dissolved salts from xylem to mesophyll.

The primary structure of a root in a cross section shows, as usual, three distinct regions, *viz.*, epidermis, cortex and stele. There are two, three or four groups of primary xylem, alternating with the corresponding number of phloem groups. A small parenchymatous pith may or may not be present. The outer region of the stele constitutes the pericycle composed of several layers of cells. A resin canal is usually formed just within the forking of each protoxylem. Outside the stele is the parenchymatous cortex, limited internally by the endodermis with characteristically thickened walls. Next

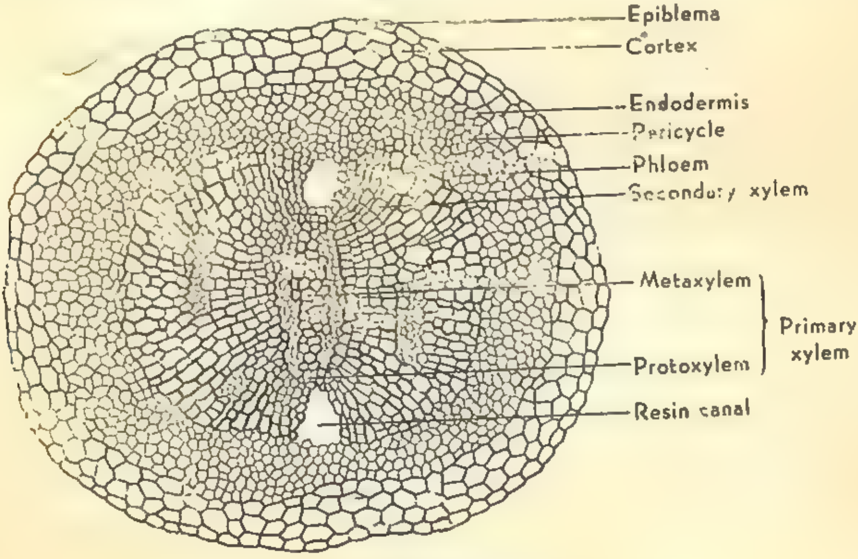


Fig. 440. *Pinus.*
T.S. of a root.

comes the epiblema as that in a dicotyledonous root. The secondary growth in thickness takes place in the same manner, as in a dicotyledonous root, by the activity of a layer of secondary cambium, which first appears as strips of cambium from the thin-walled cells between primary xylem and primary phloem. The cork cambium also originates from the outermost cells of the pericycle, and gives rise to cork outside, so that the cortex and the epiblema die to form a bark.

Pinus is monoecious, and bears both microsporophylls in *staminate strobili*, and megasporophylls in *carpellate strobili*. But bisporangiate

strobili may occur in exceptional cases, as in *P. maritima* and *P. laricio*.

Staminate (or **male**) **strobilus.** The staminate strobilus is found in clusters towards the apex of some branches. It is simple in nature, and consists of a short axis, on which there are *microsporophylls* (or *stamens*), arranged spirally. Each microsporophyll consists of a *stalk* subtending an expanded *scale-like portion*. On the under side of this scale, and to the side of the stalk, there are two *microsporangia* (or *pollen sacs*). The wall of the microsporangium consists of several layers of cells, whose inner layer, at least, forms the *tapetum*, surround-

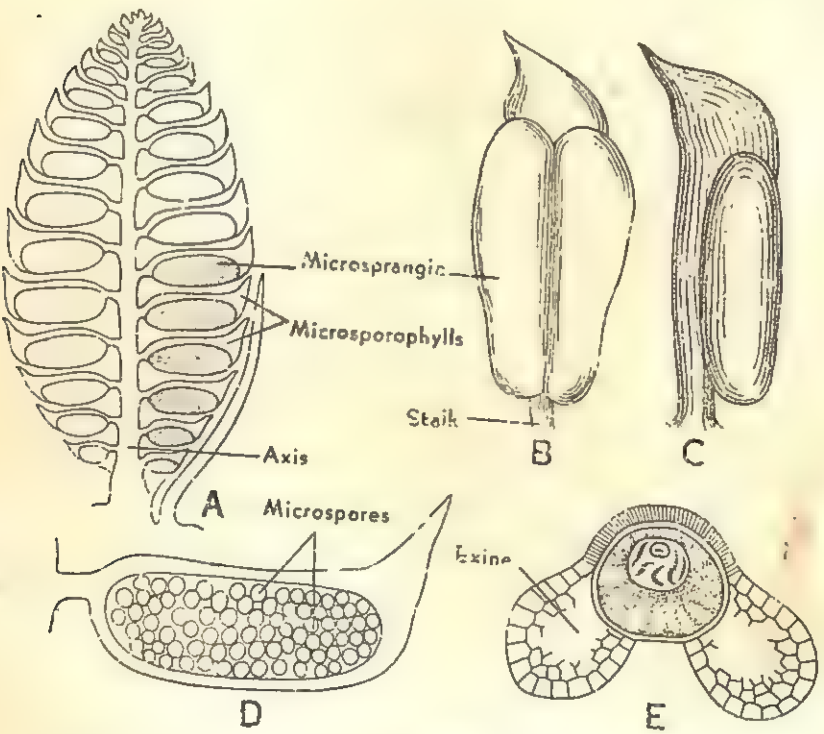


Fig. 441. *Pinus.*
A, A staminate strobilus in l.s.; B—C, Microsporophyll with microsporangia in front and side views respectively; D, A single microsporophyll with microsporangium and microspores in l.s.; E, mature microspore.

ing the spore mother-cells as in the pteridophytes. As a result of reduction division, four *microspores* (or *pollen grains*) are produced from each microspore mother-cell. Usually, the microspores are shed within a few weeks after the appearance of the strobili, which, having

performed their function, ultimately wither, and fall off from the tree. Each microspore consists of an oval cell with a conspicuously large nucleus, and has two baloon-like, air-filled **wings,** formed by the separation of the exine layer from the intine at two places, and subsequent inflation of the spaces, thus formed, between the two layers.

Carpellate (or **female**) **strobilus.** The carpellate strobili remain on the tree for a much longer period than do the staminate ones. When first formed near the tips of certain branches, they are deep red in colour, and about 1 cm. in length. Each strobilus is compound and consists of a central axis, on which *megasporophylls* (or *carpels*) are spirally arranged. A megasporophyll, when removed and viewed with a pocket lens, is found to consist of a very short *stalk* and a *scale* **(ovuliferous scale)** to which a *bract* is attached on the lower side. At the base of this ovuliferous scale, and on its upper side, there are two rounded *megasporangia* or *ovules*. Each ovule consists of an oval mass of tissue, the *nucellus*, surrounded by a single integument, and its micropyle is directed towards the stalk of the carpel. At the chalazal end, the tissues of the integument and nucellus are fused with that of the ovuliferous scale. Within this nucellar tissue there is a single central *megaspore mother-cell*, whose nucleus, by two successive divisions (reduction division), forms a linear tetrad of *megaspores* (or **embryosacs**), of which, the one, furthest away from the micropyle, functions, and enlarges considerably at the expense of the three others, which are finally absorbed.

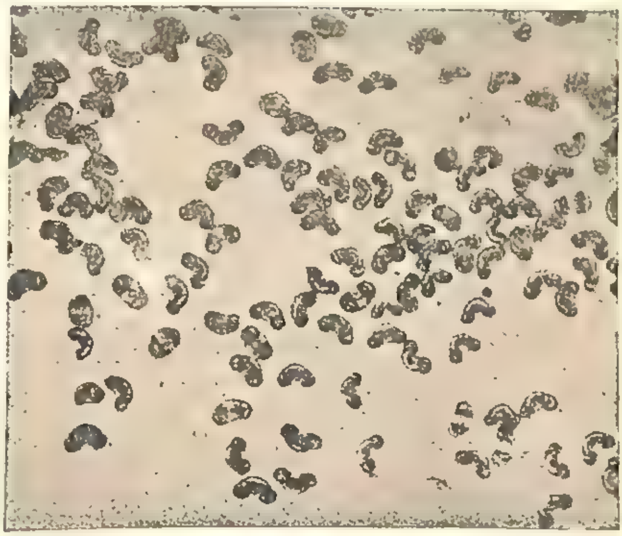
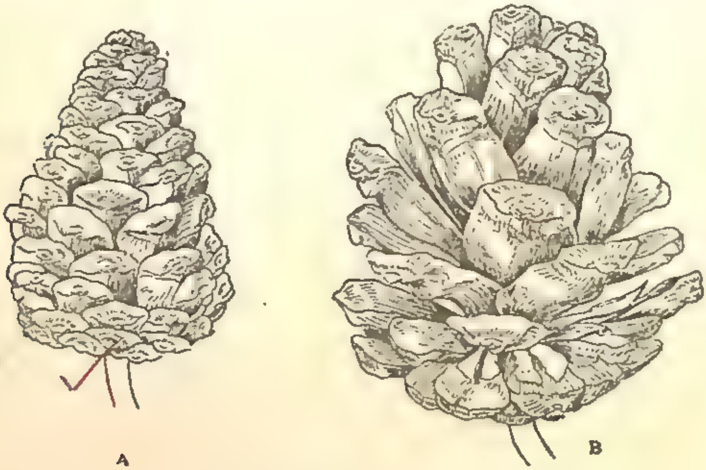


Fig. 442. *Pinus*.
Photomicrograph of the microspores.

The gametophytes

Male gametophyte. The microspores (pollen grains) begin to germinate, about a month before they are set free from the microsporangium. The nucleus first divides to form two daughter



A B

Fig. 443. *Pinus.*
A, A carpellate strobilus at the time of fertilization; B, The same several months later with scales spread apart and seeds shed.

nuclei, one of which flattens out against the spore-wall, and is cut off from the other daughter nucleus, and most of the cytoplasm by the formation of a thick wall. The cell, thus cut off, is the **first vegetative cell (first prothallial cell)**, whose nucleus rapidly degenerates. The nucleus of the larger sister cell divides again, and forms a **second vegetative cell (second prothallial cell)**, whose nucleus also behaves in the same manner, while the large persistent cell, with its prominent nucleus and cytoplasm, is called the **antheridial cell.** A little before the microspores are liberated, the antheridial cell divides to form a smaller cell, the **generative cell,** cut off against the second vegetative

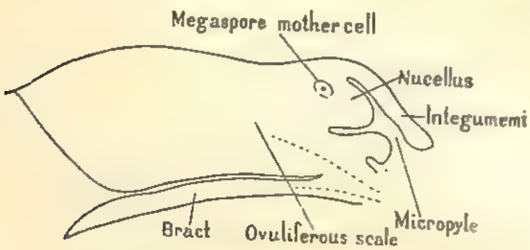


Fig. 444. *Pinus.* An ovule in l.s.

cell, and a larger cell, the **tube cell.** It is at this stage the microsporangia burst longitudinally, and the microspores (pollen grains) are liberated. The amount of pollen grains liberated by the microsporangia is astonishingly large; these fill the surrounding atmosphere, and are commonly known as **flowers of sulphur** which are disseminated by wind. During transport most of the pollen grains are wasted, but some of them reach the mature carpellate cones with their megasporophylls (or carpels) slightly separated at this time. The microspores glide between them, and remain in close proximity of the micropyles of the ovules. During this time a pollination drop consisting of a sticky

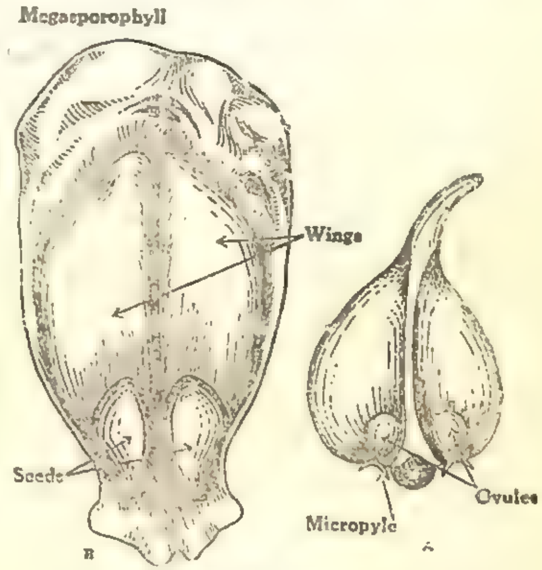


Fig. 445. *Pinus*.
A, A megasporophyll at the time of pollination; B, The same with mature seeds.

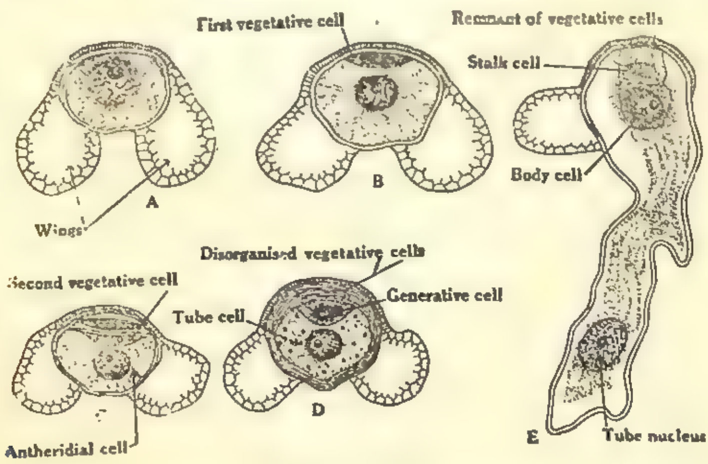


Fig. 446. *Pinus*.
A—E, Successive stages in the development of the male gametophyte.

fluid appears at the tip of the ovule, which catches some of the pollen grains. As the drop dries up, the pollens are sucked inside the nucellus. After this process, the carpellary leaves close up. Following this, during the subsequent eleven months, male gametophytes do not develop further considerably, but a short **pollen tube** may be formed from each pollen grain. The tube may branch somewhat, penetrates the nucellus, and grows very slowly, till winter sets in.

During the second spring, the pollen tube grows slowly downwards, penetrates the nucellus, and finally its tip reaches the surface of the female gametophyte. During the development, the tube nucleus first enters the pollen tube. The generative cell also divides into a **stalk nucleus** and a **body nucleus,** which also enter into the tube, where the body nucleus again divides to form two **male** or **sperm nuclei.** About the stalk nucleus cytoplasm is organized to form a definite *stalk cell*, around which there is a definite membrane. The male gametes have clearly differentiated cytoplasm, and a large nucleus.

Female gametophyte. During the year, following pollination, development of the female gametophyte takes place. The megaspore germinates within the megasporangium, and it is never set free. It first enlarges at the expense of the nucellar tissue, its nucleus divides repeatedly, without wall-formation, for a considerable length of time, forming a large number of free nuclei, distributed in the general mass of cytoplasm of the megaspore. Walls are ultimately laid

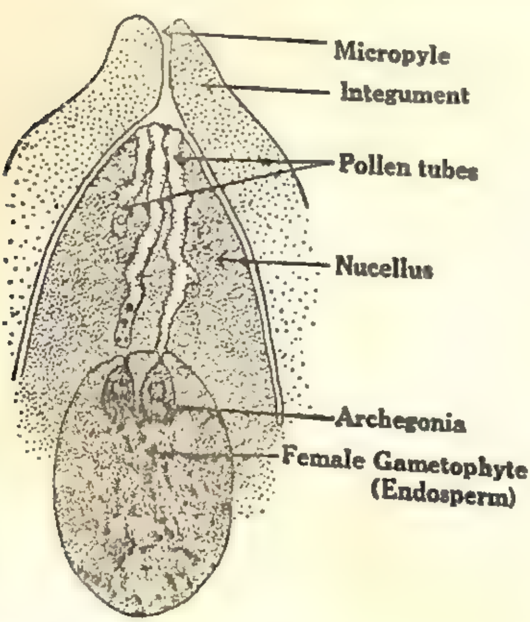


Fig. 447. *Pinus*.
Part of a longitudinal section through a megasporangium (ovule); three pollen tubes growing down into the nucellus and effecting fertilization.

down between the nuclei, and the result is the formation of a solid mass of gametophytic tissue, known as the **endosperm,** which is not homologous with the endosperm in the seeds of angiosperms. Nearly a year after pollination, there develops, at the micropylar end of the female gametophyte (endosperm), a number of **archegonia** (two or three usually), each having its origin from a superficial cell of the gametophyte. When fully developed,

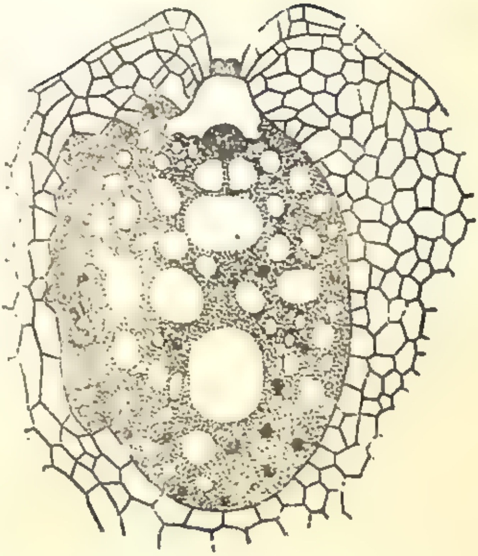


Fig. 448. *Pinus*.
Longitudinal section of an archegonium.

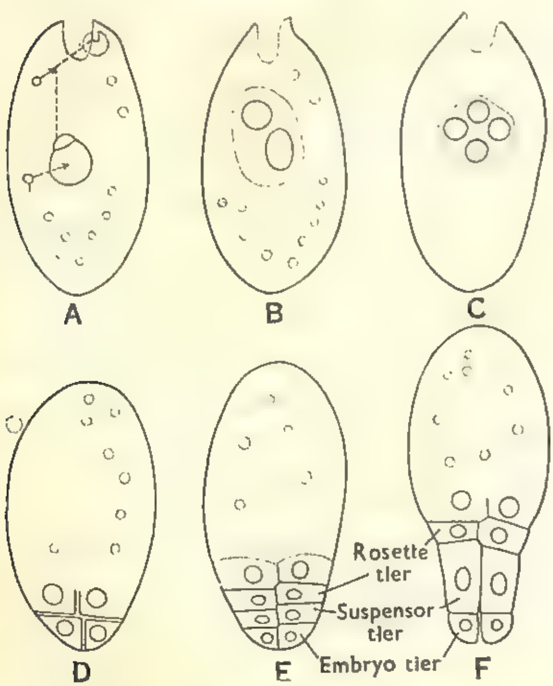


Fig. 449. *Pinus*.
A—F, Stages in the development of the embryo.

each archegonium consists of a *neck* of eight cells, in two tiers of four, the *ventral canal cell*, and a very big cavity containing an *egg*. Before fertilization the ventral canal cell disorganizes. The neck canal cells are entirely wanting, and the large cavity, containing the egg, is surrounded by a jacket layer of cells, which supplies food to the egg-cell, and ultimately to the developing embryo. The archegonia

mature, and are ready for fertilization about a year after pollination.

The tip of the pollen tube, on reaching an archegonium at the surface of the female gametophyte, destroys the neck cells, and discharges its contents into the cytoplasm of the egg. The nucleus of one male cell moves towards the egg-nucleus, and fertilizes it. The other male nucleus, the tube nucleus as well as the stalk nucleus soon disintegrate. The fertilized egg surrounds itself with a wall, and forms an **oospore.**

The new sporophyte

The fusion nucleus then passes to the base of the oospore, and, by repeated divisions, forms four nuclei, which become arranged at right angles to the long axis of the oospore. Two further divisions occur, resulting in the production of *four tiers*, each tier containing

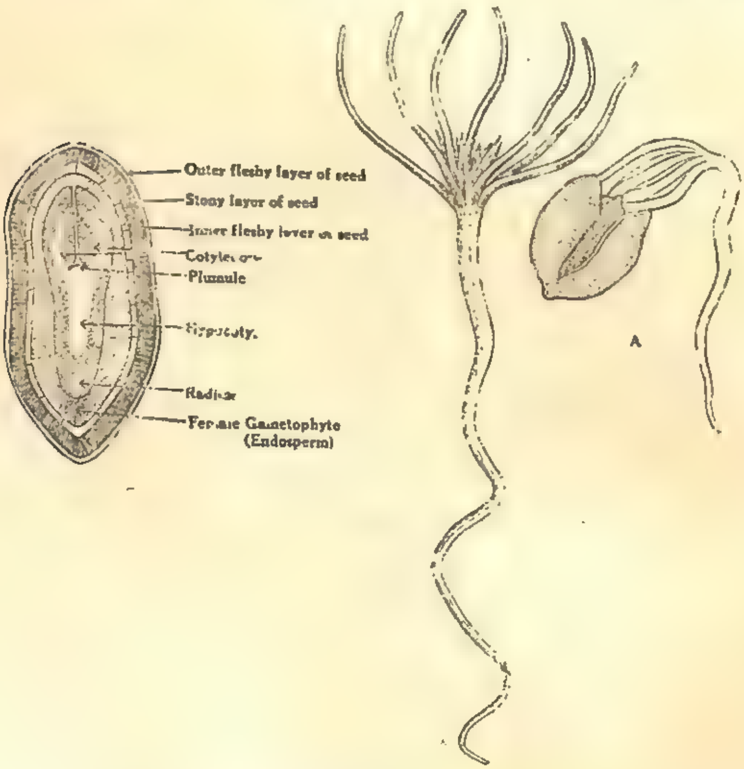


Fig. 450. *Pinus.*
A—B, Stages in the development of a seedling; C, Longitudinal section of a mature seed.

four nuclei. Partition walls develop separating all the nuclei, excepting those of the uppermost tier. The three lower tiers are known respectively, from below upwards, as the **embryo tier, suspensor tier,** and **rosette tier,** and the whole structure is termed as the **proembryo.** The embryos develop from the lowermost or embryo tier, the other tiers being only nutritive in function. The suspensors rapidly elongate, and diverge, so that the embryos are pushed deep within the tissue of the female gametophyte, which now becomes laden with food matters diffusing into it from the placenta. Each suspensor bears at its apex one of the four *embryo cells.* Four potential embryos are produced by rapid division of each of the embryo cells. It is to be noted that, as more than one oospheres may be fertilized, many potential embryos may also be produced. This is called **polyembryony,** and is a very characteristic feature of the conifers. Only one, however, attains maturity, and the rest perish during development. A fully developed embryo consists of a radicle, the hypocotyl, three to many cotyledons, and a small plumule. As the endosperm expands, the nucellus is generally crushed out, but sometimes it persists as a thin layer forming the so-called **perisperm.** The integument is gradually converted into the seed coat, and the ovule develops into a seed.

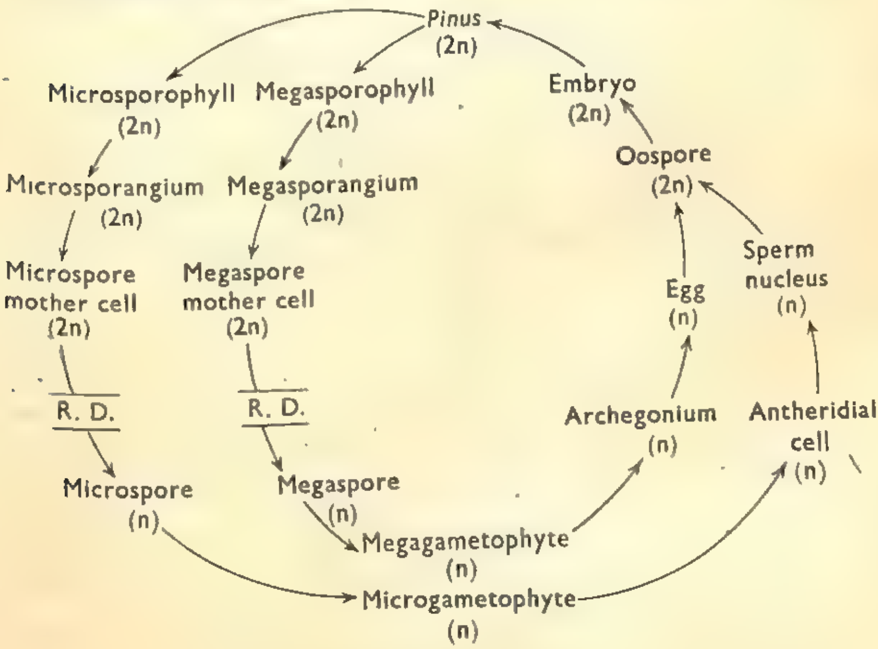


Fig. 451. Life cycle of *Pinus.*

TAXUS

(Fam. TAXACEAE)

There is only one species *Taxus baccata* (common Yew) under the genus, though, occasionally, some authors have recognized a number of species. The plant is extensively distributed over Great Britain, Germany, America, Mexico, Iran, Japan, Philippines, and India (in the western Himalayas).

The sporophyte

The plant is a slow-growing tree with an usual height of 30-40 feet, and bearing horizontally growing branches of unlimited growth forming a thick canopy. Dwarf shoots are absent. The leaves are simple, dorsiventral, slightly stalked, and are twisted at their bases, giving rise to a two-ranked arrangement. They contain silica particles, particularly so at the sharp-pointed tips. Scale leaves are absent.

Fig. 452. *Taxus*.
A, A portion of the plant bearing male strobili; B, A male strobilus.

Internally, the stem shows a general arrangement of the *Pinus* type, with the exception that the resin canals are entirely absent, and the tracheids of the secondary wood possess spiral thickenings in addition to the usual uniseriate bordered pits. The medullary rays are also uniseriate, and wood parenchymas are absent.

The root is diarch, and is also devoid of resin canals, and possesses spiral thickenings in the tracheids.

The internal structure of leaf resembles that of a leaflet of *Cycas* in some respects. There are two cuticularized epidermal layers, the upper one being continuous, while the lower one is interrupted at intervals by sunken stomata. The mesophyll is differentiated into upper palisade, and lower spongy parenchymas; sometimes the latter may contain some resinaceous, yellow-coloured matter within some cells. There is a solitary vascular bundle in the centre surrounded by an endodermal layer, with xylem towards the upper surface and phloem towards the lower one. The pericycle is modified into **transfusion tissue.**

Taxus is dioecious, and the male flowers are borne in strobili, while the female ones do not form any cone.

Staminate (or **male**) **strobilus.** The staminate strobili are borne in the axils of leaves, produced on branches of the previous year. Each strobilus consists of a short central axis, bearing about a dozen of spirally-arranged scales, in basepetal order of development, at their bases and a cluster of closely-inserted, umbellate *microsporophylls* at the top. It is to be noted that the vegetative apex is also utilized in the production of sporophyll. Each microsporophyll is a peltate, shield-

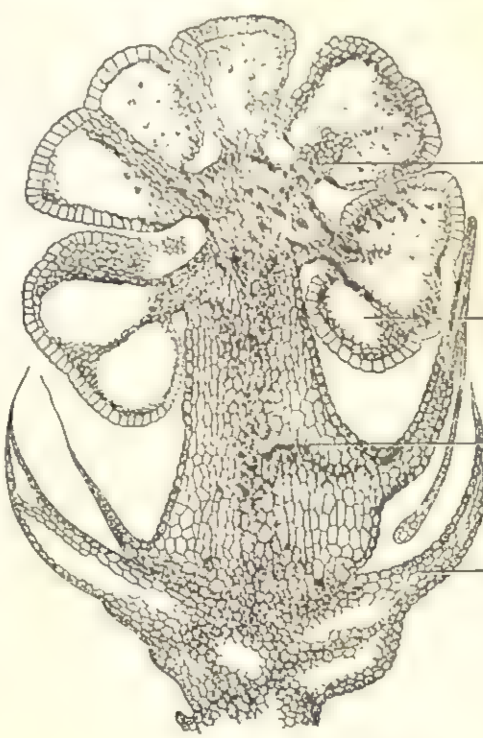


Fig. 453. *Taxus*.
L. S. of a male cone.

like body with 6-8 pendant *microsporangia*, hanging from the under surface of the shield. These sporangia are united with one another, as well as with the sporophyll-stalk. The microsporangia contain numerous microspore mother-cells, each of which on undergoing reduction division, gives rise to a tetrad of *microspores* or *pollen grains*. The pollen grains are liberated by the dehiscence of the sporangium, and are dispersed by the wind. They come in the neighbourhood of the ovule, and are caught by the pollination drop, exuded from the micropylar end of the ovule.

Megasporangium (or **Ovule**). The ovules occupy the same axillary position on the female plants, just as the male cones do in the male ones. There is also a short central axis, which is known as the **primary axis,** bearing a number of closely-imbricated, overlapping, sterile scale leaves on its basal region. In the axil of the uppermost scale there arises the fertile shoot, the **secondary axis,** which bears three pairs of decussately arranged minute scale leaves, the lowermost pair of which stands at right angles to the subtending bracts. This secondary axis apparently terminates in a solitary ovule. The vegetative apex of the primary shoot may occasionally proliferate, producing another secondary axis, bearing an ovule in the next year.

Fig. 454. *Taxus*.
A, A portion of the plant showing female flowers; B, A female inflorescence.

The ovule is orthotropous. The nucellus is free from the integument. The latter is

three-layered as usual and forms a prominent micropylar canal above the nucellus. In some cases, in the adult stage the nucellus and the integument may be fused. Just below the integument, there appears a slowly-growing ring-like structure, which later on surrounds the entire ovule. This is usually known as the **aril,** but it cannot be compared to the structure bearing the same designation as is found in the angiosperms. On the contrary, it can be compared with the epimatium of the *Podocarpus*, while others consider it to be an outer integument. This structure is also referred to as the **cupule** by some authors. With the maturity of the seed it becomes red, and gives the seed a characteristic berry-like appearance.

The gametophytes

Male gametophyte. The microspore is the first cell of the male gametophyte. The development of the male gametophyte begins at the pollination-stage in the middle of March. The pollen grain is shed in a uninucleate stage, and the formation of any prothallial cell is completely eliminated. Pollination takes place by the agency of wind. The division of the pollen-nucleus results into an **antheridial cell,** and a **tube cell.** The former divides later on into a **stalk cell,** and a **body cell.** The body cell, by undergoing another division, gives rise to two unequal cells, which finally develop into two dissimilar non-flagellate *male gametes*.

Female gametophyte. The megaspore is the first cell of the female gametophyte. The megaspore nucleus divides freely, and gives rise to 256 nuclei. The cell, in the meanwhile, enlarges rapidly, and these nuclei are placed peripherally around a central vacuole. Subse-

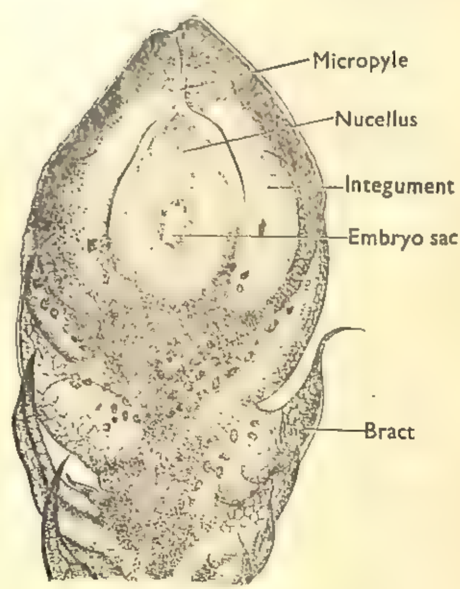


Fig. 455. *Taxus*.
L.S. Through an ovule and an ovuliferous branch.

quent to this, wall-formation begins. The walls are laid down at right angles to the megaspore-membrane, and they extend to the

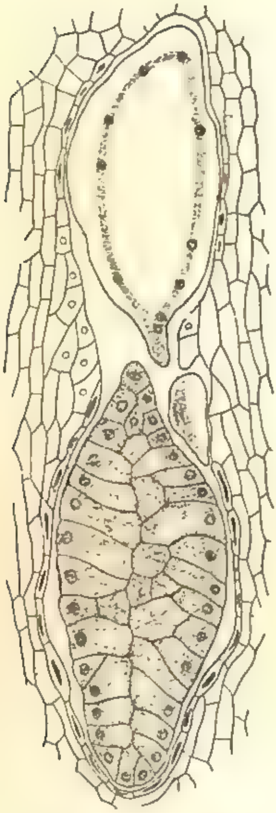


Fig. 456. *Taxus.*
Development of endosperm.

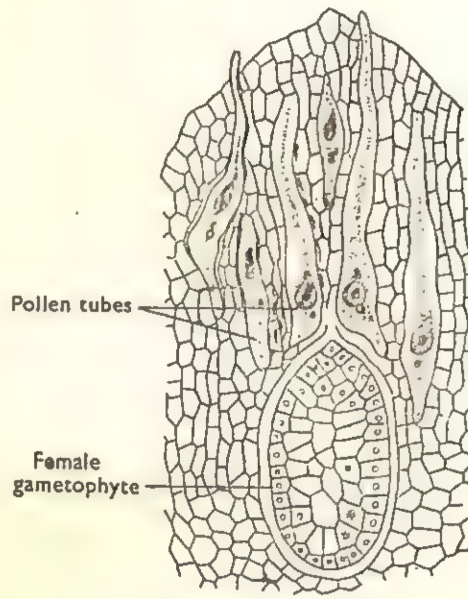


Fig. 457. *Taxus.*
A number of pollen tubes growing towards the female gametophyte.

middle of the megaspore cavity, giving rise to long tube-like cells known as the **alveoli.** In almost all cases, the centripetal ends of the alveoli are provided with walls only at a later stage. Subsequently, further divisions of the alveoli take place, resulting in a large number of cells forming the **endosperm** (the female gametophyte). The cells of the endosperm are uninucleate at first, but later on the number of nuclei in each may multiply during the month of July. Ultimately, the nuclei in each cell degenerate, and undergo fusion, forming a single, large, irregular body. The *archegonia*, 5-8 in number, develop from the superficial cells at the top of the endosperm. The structure of the archegonium is rather simple. There are four *neck cells*, and only one *egg cell* in the venter; no ventral canal cell has yet been recorded.

The interval between pollination and fertilization is a short period of one month only. The pollen tube, developed from the tube cell, reaches the female gametophyte at a period, when the latter may be in a comparatively early state of development, or in other words, the archegonium-initial may not have yet been recognized. The tip of the pollen tube finally ruptures, and all the four nuclei enter into the archegonium, but only the larger of the two male nuclei unites with the egg forming *oospore*, while the remaining three degenerate*. Several archegonia may be thus fertilized, giving rise to a case of simple **polyembryony,** but normally only one embryo reaches maturity.

The new sporophyte

The oospore undergoes a number of free nuclear divisions, resulting in 32 nuclei, which migrate to the base of the developing sporophyte. At this stage walls begin to be formed separating the nuclei into cells, constituting the **proembryo.** The cells of the proembryo are arranged in three tiers. From the lowermost tier (which as a

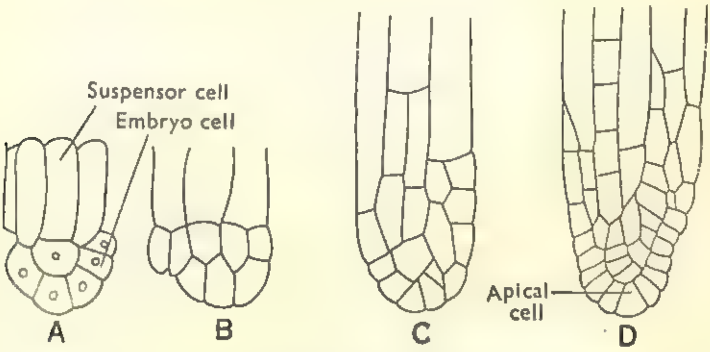


Fig. 458. *Taxus.*
A—D, Successive stages in the development of the embryo.

rule is composed of one cell only) the *embryo* is developed. The other tiers of cells give rise to the *suspensor*. The mature embryo is dicotyledonous, and in course of its attaining maturity, consumes the endosperm wholly. The aril of the mature seed, on account of its red colour, attracts the birds, and thus the seed is dispersed

*According to Chamberlain, "In *T. baccata* only the larger sperm enters the egg, the smaller sperm, and both the stalk and tube nuclei remaining in the pollen tube."

through their agency. The germination of the seed is hypogeal, and on germination, it gives rise to a seedling sporophyte.

ORDER 7. GNETALES

No fossil record of the Gnetales have been obtained below the Tertiary, and consequently, the Order may be regarded as a comparatively younger one. The members of this Order occur both in the eastern as well as in the western hemispheres, excepting *Welwitschia mirabilis*, which is practically endemic to the Namib desert area of South-West Africa.

Plants woody, sparsely branched and usually dioecious; leaves simple, opposite and net-veined like those of the dicotyledons; 'flowers' with a distinct perianth and generally forming cones; embryo with two cotyledons; endosperm copious; true vessels present in the secondary wood; resin canals absent.

The Order includes only *one* family **Gnetaceae***. Pearson records about 67 species under Gnetales—32 species for *Ephedra*, 34 for *Gnetum*, and only 1 for *Welwitschia*.

EPHEDRA

(Fam. Gnetaceae)

The species of *Ephedra* are found distributed in North as well as in South America, Spain, France, the Mediterranean regions, and India. It is interesting to note that, not a single species has yet been recorded, which is common to both the hemispheres. According to Hooker, there are three species of *Ephedra* growing in India: *E. vulgaris*, *E. pachyclada*, and *E. peduncularis*. From *Ephedra* a valuable alkaloid '*ephedrine*' is extracted, which is extensively used in bronchial troubles.

The sporophyte

Plants are low-growing shrubs, while a few are woody climbers, or prostrate. In some places they serve as sand-binders. The plant is highly xeromorphic, and grows on rocks or in sandy places. The leaves are rudimentary, and practically of no importance to the

* Recent workers suggest that not only the three genera, *Ephedra*, *Gnetum*, and *Welwitschia*, do belong to the separate families Ephedraceae, Gnetaceae, and Welwitschiaceae, but also come under distinct orders Ephedrales, Gnetales, and Welwitschiales respectively.

plant, as the stem itself is a ribbed phylloclade. They are usually decussately arranged, but may occur in whorls of three, very rarely of four. They are connate at their bases, forming a small sheath. The branches appear in two's or three's from the axillary buds, and may fall off in some species at the end of the growing season, and are replaced by new ones in the next season; such species may be regarded as **deciduous** ones, by analogizing them with trees shedding off their leaves in winter.

Internally, the stem has got a conspicuously thick epidermis, and groups of sclerenchyma cells occur below each rib. Sunken stomata occur in the furrows. The cortex is loose in texture, and differentiated into an outer palisade and inner spongy tissues, the cells of both of which contain abundant chloroplasts. Below the cortex there is an endodermal layer, encircling an endarch, siphonostelic vascular

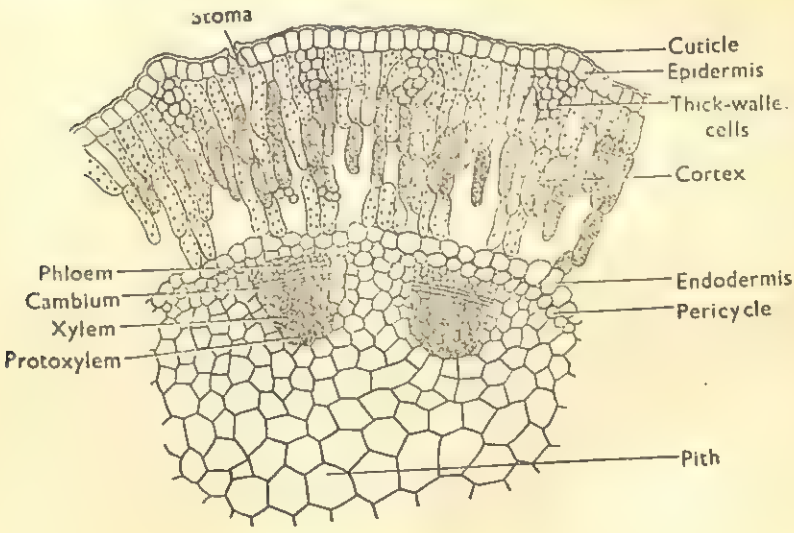


Fig. 459. *Ephedra*.
T.S. of a young stem.

cylinder, the bundles of which are conjoint, collateral, and open. The tracheids are provided either with single or alternating double rows of bordered pits, with bars of Sanio and trabeculae. In young stems, the medullary rays are uniseriate. At or near about the nodes, the cells of the pith get highly lignified, and form transverse plates. Resin canals are entirely absent, but cells containing large, stellate, calcium oxalate crystals are frequently met with. A group of thick-

walled cells with dense cell-contents (most probably tannin) occur in the centre of the pith. The stem grows in girth due to secondary growth, and prominent annual rings are formed. The secondary wood possesses vessels in addition to tracheids.

Ephedra is dioecious. It is interesting to note, however, that though normally male and female strobili are borne on different individuals, yet monoecious plants are not rare in nature, e.g., *E. foliata*. Furthermore, bisporangiate flowers may be found in species like *E. camphylopoda*, *E. trifurca*, etc.

Staminate (or **male**) **strobilus.** Staminate strobili occur in groups of two, three or four, from the nodes of the branches. Each

A B

Fig. 460. *Ephedra*.
A, A portion of the plant bearing male strobili; B, A single male strobilus.

strobilus is a compound one, appears in the axil of a leaf, and consists of a short axis, bearing 2-8 decussately arranged bracts; the lower

1-2 pairs of bracts are usually sterile, while each of the rest bears a single male flower. Each male flower is represented by a single stamen, having a stalk bearing a variable number of *microsporangia* (or *anthers*) at its tip, subtended at the base by a pair of delicate, oppositely placed **scales,** which coalesce together forming a structure that has been doubtfully interpreted as a **perianth.** The stalk bearing the microsporangia has been referred to by some as **sporangiophore** or **antherophore.** Each microsporangium is 2-3 lobed, and the lobes open by apical slit. The microspore mother-cells (or pollen mother-cells) inside the microsporangium, on undergoing reduction division, give rise to *microspores* or *pollen grains.*

Pistillate (or **female**) **strobilus.** The mode of distribution of the female strobili is practically the same as that of the male

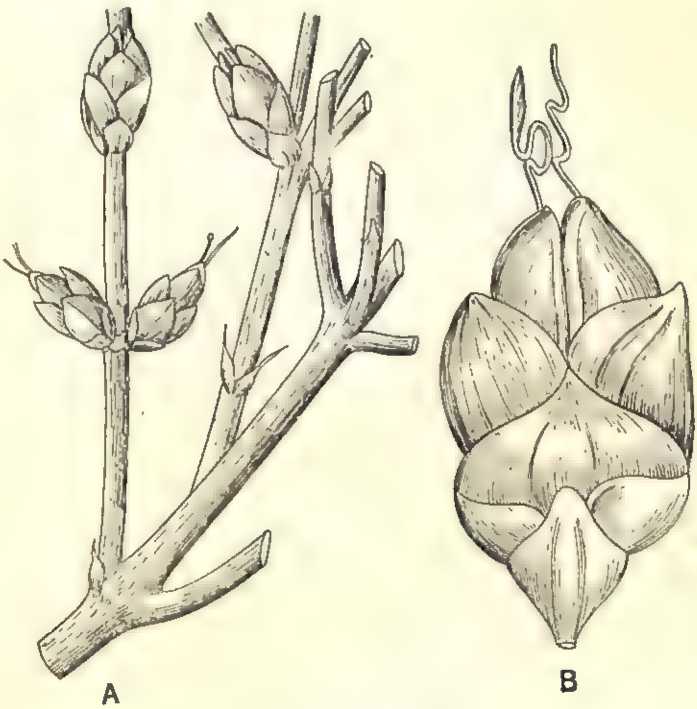


Fig. 461. *Ephedra.*
A, A portion of the plant bearing female strobili;
B, A female strobilus.

ones, and their structures are also very similar. The former ones are, however, rather shorter and more pointed, than the latter. Each strobilus consists of a few pairs (usually 4) of sterile bracts, and

either a solitary *ovule* or 2-3 of them. The bracts may be fleshy or dry, and winged, and sometimes highly coloured for the purpose of effective dispersal by animals or wind, as the case may be.

The structure of the ovule is fundamentally the same as in other gymnosperms. There is the **nucellus** surrounded by two integuments, the outer one being formed by four segments (**bracts**), coalescent at the base, and the inner integument is formed of two such coalescent bracts. The upper portion of the nucellus is separate from the inner integument, which, at the time of pollination, prolongs out considerably, giving rise to a smooth or spirally-coiled **micropylar tube.** The pollination drop is exuded at the tip of this micropylar tube. At the tip of the nucellus there is a conspicuously deep **pollen chamber,** whose bottom actually touches the apex of the female gametophyte (endosperm).

The gametophytes

Male gametophyte. The microspore or pollen grain is the

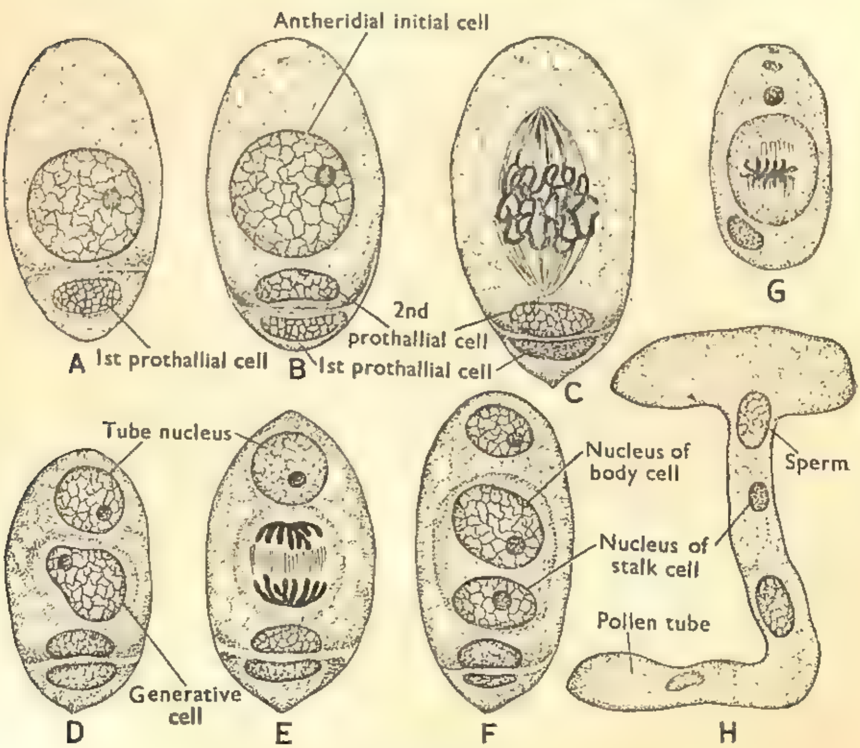


Fig. 462. *Ephedra.*
A—H, Successive stages in the development of the male gametophyte.

first cell of the male gametophyte. The mode of development in this case follows the plan as found in *Pinus*. It is to be noted, however, that the **prothallial nucleus,** formed as a result of the second division, is not separated from the rest (*antheridial initial*) of the developing gametophyte by means of a wall. The antheridial initial divides to form a **tube cell,** and a **generative cell,** the latter dividing in its turn and giving rise to two nuclei, a **stalk cell-nucleus,** and a **body cell-nucleus;** these two nuclei invariably lie enclosed within a common cytoplasmic envelope, and there is no formation of a cell wall in between the two. The pollen grains are liberated at this stage. Before the shedding, however, the two prothallial cells get completely disorganized. Pollination is effected sometimes in early March. On reaching the ovule, the body cell divides, and forms two identical **male gamete-nuclei.** Finally, the exine bursts open, and the intine pushes itself out into a short pollen tube.

Female gametophyte. The megaspore is the first cell of the female gametophyte. As in all other gymnosperms, the functional megaspore develops from the lowest of a linear tetrad of megaspores, and undergoes a period of free nuclear division. At the 256 nuclear stage, cell walls begin to be laid down rapidly in a centripetal fashion, and finally the female gametophyte (endosperm) becomes entirely cellular. Even before the female gametophyte is cellular throughout, a differentiation takes place inside it forming two regions, an *upper reproductive* one composed of large elongated cells, and a *lower nutritive* one made up of compara-

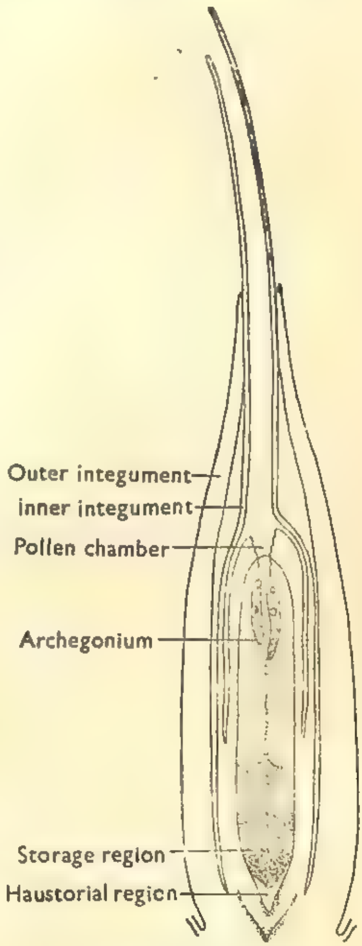


Fig. 463. *Ephedra*. L.S. of a mature ovule.

tively much smaller cells. Finally, the lower nutritive region gets further differentiation into an upper tissue performing the function of reservoir of food, and a lower mass of cells constituting a **haustorium,** which absorbs nutrients from the nucellus.

At the micropylar end of the endosperm, **archegonia** develop, usually two in number; occasionally, there is only one archegonium, and rarely there are three. The number of neck cells are rather heavy in *Ephedra*, and stands at 32 or more. There is no wall formed in between the ventral canal-nucleus and the egg-nucleus.

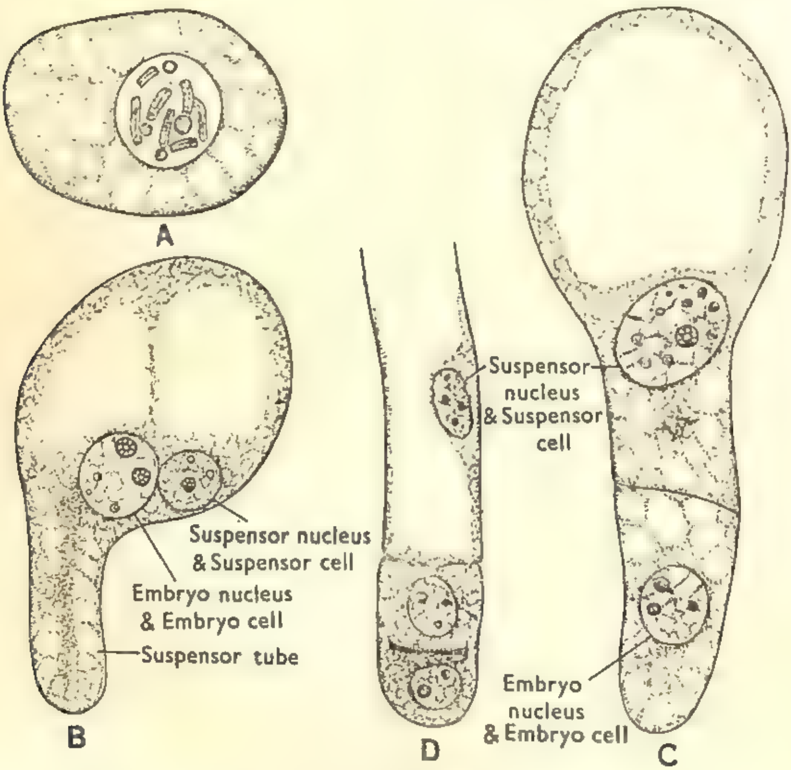


Fig. 464. *Ephedra*.
A—D, Successive stages in the development of the embryo.

The time interval in between pollination and fertilization is exceptionally short for a gymnosperm, and is less than a period of 12 hours. The short pollen-tube pierces through the neck of the archegonium, and by the bursting of its tip, the contents are discharged in the egg. The first male gamete-nucleus actually unites

with the egg-nucleus forming **oospore,** while the second male gamete-nucleus and the ventral canal-nucleus undergo divisions producing the nuclei for a few, minute, very short-lived cells at the top of the oospore; their further details are not clearly known. But this tissue is considered, by some workers, as equivalent to the endosperm of the angiosperms, at least physiologically, as it is readily absorbed by the developing embryo. On the other hand, Herzfeld describes the fusion of the second male gamete-nucleus with the ventral canal-nucleus, and calls it a case of **double fertilization** as found in the angiosperms.

The new sporophyte

The oospore-nucleus divides freely, and usually forms eight nuclei, which remain more or less evenly distributed throughout the cytoplasm. Each of these nuclei is organized into a cell, and can be regarded as a potential young embryo; this is an instance of **polyembryony,** where no cleavage takes place. Normally, 3-5 of these embryos begin further development. At first, the embryo-cell-nucleus divides into two unequal parts without any corresponding cell wall formation. A small tubular outgrowth is developed, and the larger nucleus passes into it moving towards the tip, behind this, a transverse wall is formed. The terminal cell, thus cut off, divides, and forms the **proembryo,** from the tip of which the *embryo* is developed. The remaining portion of the tube with its nucleus forms the *suspensor*, which elongates subsequently and helps in pushing the developing sporophyte (embryo) down within the nutritive tissue. The cells of the proembryo lying behind the tip also elongate to some extent, and form the **secondary suspensor.** Only one embryo, however, usually reaches maturity. The seed is dicotyledonous with two linear cotyledons, and the mode of germination is hypogeal. On germination the seed gives rise to a seedling sporophyte.

GNETUM

(Fam. GNETACEAE)

Gnetum grows luxuriantly in the tropical forests of both hemispheres being mostly distributed in tropical Asia, and in the lands between Asia and Australia. According to Hooker, there are

6 species of *Gnetum* in India, viz., *G. gnemon*, *G. macrostachyum*, *G. scandens(?)*, *G. funiculare*, *G. neglectum*, and *G. macropodum*. Maheshwari and Vasil (1961) record five species of *Gnetum* from India. These are *G. ula*, *G. gnemon*, *G. latifolium*, *G. contractum*, and *G. montanum*. Of these the first-named species is the most common. *G. gnemon* and *G. latifolium* possess two varieties each, namely *G. gnemon* var. *brunonianum*, *G. gnemon* var. *griffithii*, *G. latifolium* var. *macropodum* and *G. latifolium* var. *funiculare*.

The sporophyte

The plants are mostly lianes (*G. ula*), which climb or trail over other vegetation, often reaching the tops of the tallest trees. A few species are, however, small trees (*G. gnemon*, *G. costatum*) and shrubs. The leaves are simple, large, oval, entire, exstipulate, leathery, and with short petioles. They show pinnately reticulate venation resembling the foliage leaves of dicotyledons, and are arranged on the stem in opposite-decussate pairs. The branches are of two kinds: one of limited growth or **dwarf shoot,** and the other of unlimited growth or **long shoot.** In climbing species the foliage leaves are borne on dwarf shoots only, while those on long shoots are usually reduced to scales. In case of a tree (*G. gnemon*), the differences between these shoots are very much reduced.

In transverse section of a young stem of *Gnetum*, whether belonging to the arborescent types (*G. gnemon*) or to the climbing ones (*G. ula*), shows a somewhat circular outline. The epidermis is single-layered and made up of rectangular cells, whose outer walls are thick and heavily cuticularized; sunken stomata are present. The cortex is many-layered and consists of polygonal or rounded parenchyma cells with chloroplasts. Lying within the cortical tissue a number of scattered sclerotic cells or sclereids are found, which in little older stems form a conspicuous irregular ring. This is commonly known as the ring or zone of **spicular cells.** The endodermis as well as the pericycle, however, cannot be clearly differentiated. The vascular bundles, varying in number, are arranged in a circle, and are collateral and open in nature. The phloem consists of sieve tubes, phloem parenchyma and well-developed phloem fibres. The xylem is endarch and made up mainly of tracheids and a few vessels or trachea. *The presence of true vessels is an angiospermic character found in Gnetum.* Broad and long, conspicuous medullary rays separate the vascular bundles from one

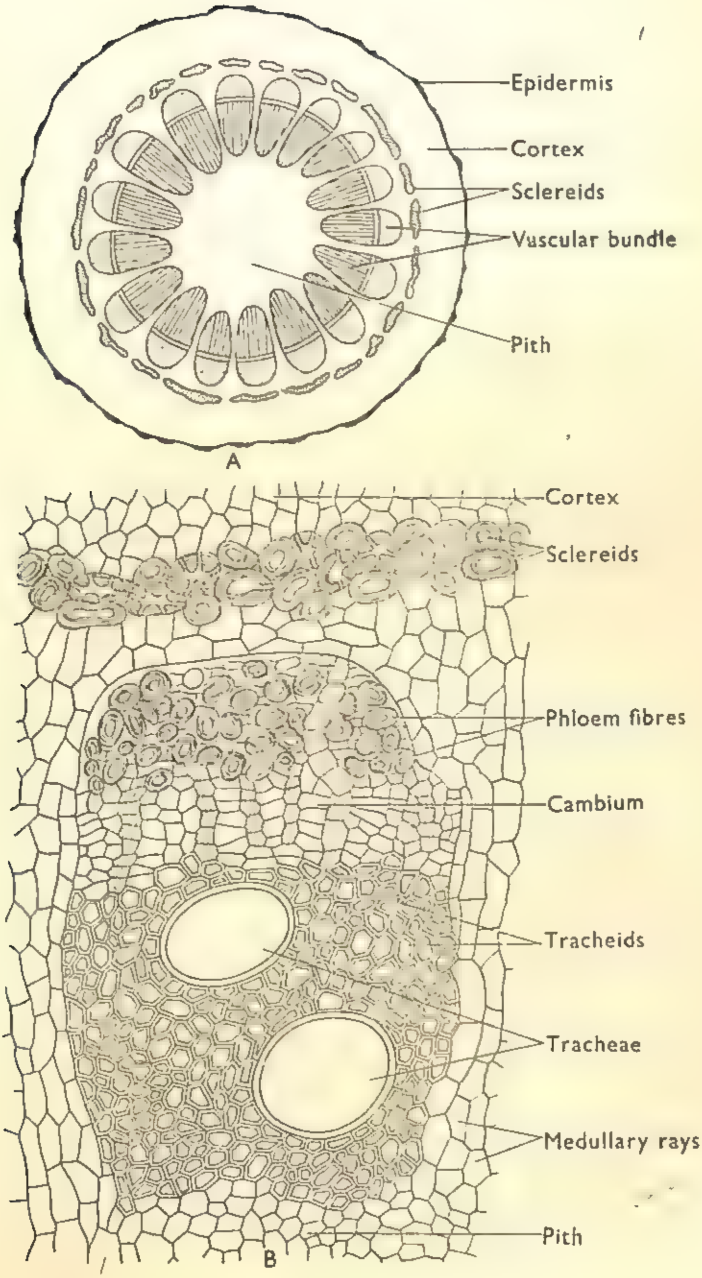


Fig. 465. *Gnetum.*
A, A transverse section of a young stem; B, A portion of the same (magnified) to show the different tissues.

another. The pith is more or less circular and consists of thin-walled parenchyma cells. In somewhat older stems, however, the cells of the pith lying towards the vascular bundles become lignified.

Secondary growth in the stems of *Gnetum* takes place in the normal fashion. In the case of lianes, however, though secondary growth commences normally, during later stages, secondary cambium arises at different regions within the deeper layers of the cortex. As a result, anomalous rings of secondary vascular bundles (either complete or incomplete) are produced successively.

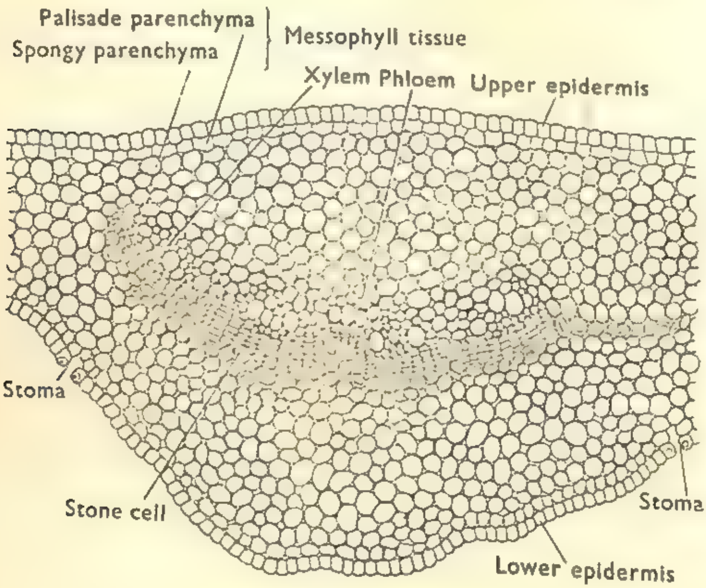


Fig. 466. *Gnetum*.
A transverse section of a leaf (in part).

A transverse section of a young root of *Gnetum* exhibits the following structure : The epiblema is single-layered. The cortex is composed of a large number of layers made up of conspicuous starchgrain-containing polygonal cells; within these cortical cells numerous fibres can be observed. Below the cortex there is an endodermis, which encloses within it a few-layered pericycle. The vascular bundles are diarch with a rather poor amount of primary xylem. The pith is also inconspicuous. Secondary growth is of the normal type, some of the xylem elements in a mature root contain starchgrains.

A cross section of the leaf of *Gnetum* seems to differ in no essential feature from that of a dicotyledon. The epidermal layers are provided with a thick cuticle. Numerous stomata occur entirely on the lower epidermis. The mesophyll consists of a single layer of upper palisade cells, and a well-developed lower spongy tissue. Within the latter stellately branched sclereids occur, particularly near the lower epidermis. A large number of latex tubes and fibres are present within the mesophyll tissue, more conspicuously in the midrib region of the leaf. In the midrib the vascular bundles are arranged forming a distinct curve. In some species a curved ring of sclereids is formed outside the phloem zone, whose cells are arranged in regular rows. Above the phloem there lies the xylem consisting of tracheids, vessels and xylem parenchyma.

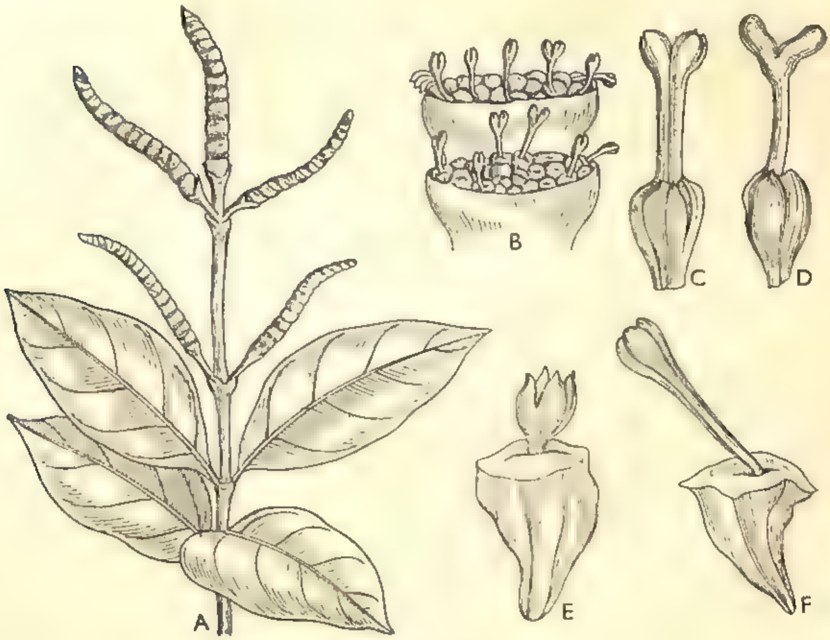


Fig. 467. *Gnetum*.
A, A branch bearing a cluster of staminate strobili; B, A portion of the same (enlarged); C—F. Male flowers in different stages of development.

In *Gnetum* the microsporophylls and megasporophylls form different strobili and the plants are mostly dioecious.

Staminate (or **male**) **strobilus.** It consists of a slender axis

with numerous pairs of decussate bracts, which are connate throughout, thus making them look like cups. In the axils of these cups, surrounding the axis, numerous **staminate flowers** develop. Each staminate flower consists of a stalk bearing at its tip two anthers, each with a single microsporangium, and invested at the base by two connate bracts (the **perianth**). The strobili are axillary or terminal, solitary or in catkin-like clusters, and are compound structures, since the microsporangia are borne on secondary axes.

Fig. 468. *Gnetum.*
A, A branch bearing a cluster of ovulate strobili; B, An older ovulate strobilus bearing a few mature ovules; C, A ripe seed.

The presence of the perianth is a striking angiospermic character. The flowers mature in an acropetal order. Our knowledge about the development of microsporangium and *microspores* (*pollen grains*) is still very incomplete. Within the microsporangium gradually sporogenous cells become differentiated, and from these ultimately, by reduction division, spore-tetrads are formed. The outer wall of the anther consists of a single layer of cells, and the tapetum is formed from the outer sporogenous tissue, and not from the wall. As the microsporangia mature, all the cells between the microspores and the epidermis break, and the microspores are liberated.

Ovulate strobilus. The structure of the ovulate strobili resembles in general that of the staminate strobili, *ovules* or *megasporangia* arising in the axils of connate bracts. There are five or six whorls of ovules surrounding the axis, and with five to seven ovules in each whorl. Sometimes the axis is terminated by a single ovule. Though there are numerous ovules, only a few attain maturity. Each ovule is invested with two integuments; the inner one becomes prolonged into a **micropylar tube,** which is a characteristic feature of the genus. The nucellus has all the characteristic features of the gymnosperm, consisting of a heavy mass of sterile tissue overlying the megaspore mother-cell. It is quite probable that in some cases more than one megaspore mother-cells may be organized within a single ovule. The tip of the nucellus becomes more or less disorganized and shallow (*G. gnemon*), and this is the only trace of the pollen chamber found in other gymnosperms. A deeper and narrower pollen chamber may be formed in some cases (*G. africanum*). The megaspore mother-cell, as usual by reduction division, forms four cells, each of which may become an **embryosac;** thus, when several megaspores begin to function, several gametophytes may be produced within a single ovule. Other details about the development of the embryosac are still incomplete.

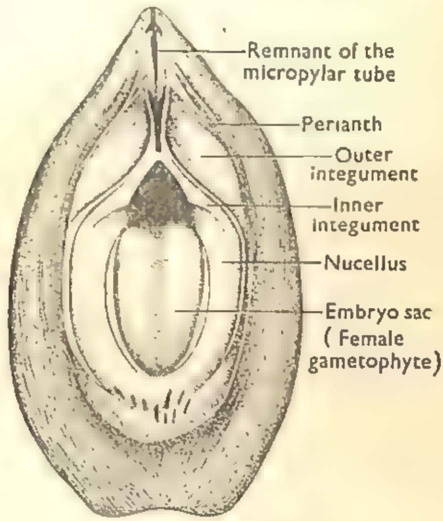


Fig. 469. *Gnetum*. Median longitudinal section of a mature ovule.

The gametophytes

Male gametophyte. A young pollen grain of *Gnetum* is usually provided with a thick spiny exine and a thin intine. In both the commonly occurring species, *G. ula* and *G. gnemon*, Negi and Madhulata (1957) noted that after first nuclear division in the microspore or pollen grain, a small lens shaped cell is cut off at one end. This

subsequently becomes rounded but neither divides any further nor it does take part in the development of the pollen tube. On the other hand, it degenerates *in situ*, and is, therefore, regarded as a **prothallial cell.** The sister nucleus, however, divides again giving rise to two nuclei, the **tube nucleus** and the **generative**

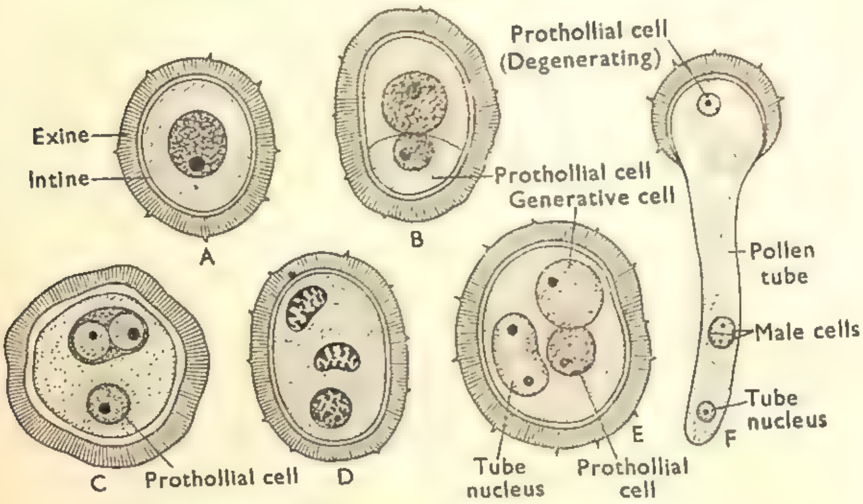


Fig. 470. *Gnetum.*
A, A mature pollen grain; B—F, Stages in the development of male gametophyte.

nucleus. This generative nucleus soon develops a cytoplasmic sheath around itself to form a **generative cell.** Thus, a mature pollen grain contains a prothallial cell, a generative cell and a tube nucleus, lying in close proximity.

At the time of germination of the pollen grain, which takes place inside the pollen chamber, the exine is cast off and the intine is pushed out in the form of **pollen tube.** The tube nucleus is the first to enter the pollen tube and is followed later on by the generative cell. The generative cell finally divides to form two **male cells.**

Female gametophyte. The development of female gametophyte in *G. gnemon* and *G. ula* is distinctly tetrasporic. So far as known *Gnetum* is the only gymnosperm showing this type of development of the female gametophyte, though such a condition can be frequently met with in a number of angiospermic plants.

At the end of meiosis in the megaspore mother-cell, a four nucleate

coenomegaspore is formed. Further development takes place with free nuclear divisions within the megaspore. A conspicuous vacuole appears in the central portion of the developing gametophyte and the nuclei lying in the peripheral layer of cytoplasm undergo

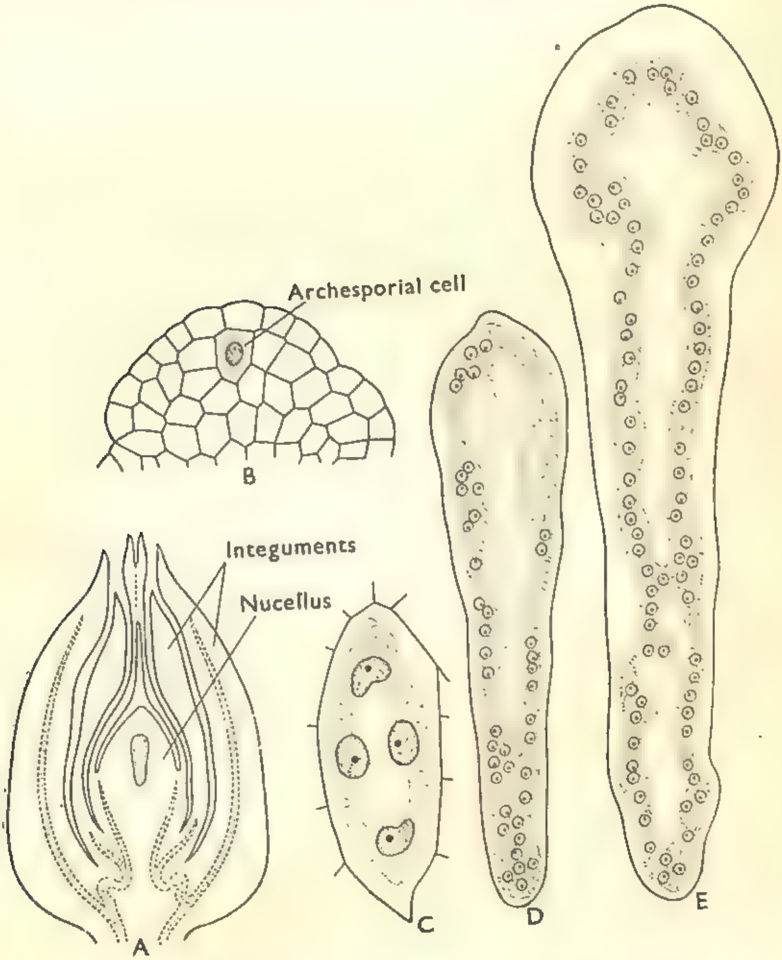


Fig. 471. *Gnetum*.
A, L.S. of an ovule (diagrammatic); B—E, Stages in the development of female gametophyte.

further divisions; these number of divisions vary in different species. In addition to a normally developing main gametophyte, there may be 2-4 accessory gametophytes (which are smaller in size and contain a few nuclei only). These accessory gametophytes are

usually placed above the main gametophyte and ultimately undergo degeneration. *No archegonium is present within the gametophyte which is an angiospermic character.*

Fertilization

After the entry of pollen tube into the female gametophyte, whose lower end has become partly cellular, one or more nuclei (3-8) at its upper end also become delimited by cell walls. These groups of cells are usually present in the neighbourhood of the pollen tube. Out of each such group, one or rarely two cells behave as egg cells, which often become surrounded by a layer or two of minute and degenerated cells. In all probability these inconspicuous cells provide nourishment to the egg and become used up at the time of fertilization. Only a male nucleus enters the egg, while its sheath is left outside. In cases where two eggs are present in the vicinity of the pollen tube, double fertilization may result.

Gnetum is remarkable among gymnosperms in the fact that a typical gymnospermic endosperm, which is formed prior to fertilization, is lacking here. Madhulata (1960) reports in *G. gnemon* that while eggs are being differentiated, the female gametophyte remains in a free nuclear condition, and only when zygotes are produced in the micropylar region of the ovule, the first walls are laid down in the chalazal region producing in an upward direction. Very rarely the cell wall formation may take place simultaneously throughout the gametophyte. Sometimes walls may be laid down even when eggs are not differentiated within the gametophyte.

The new sporophyte

After fertilization, the zygote develops into the embryo. The details of the embryo-development, however, are not clear and much confusion exists, which may be attributed to variations existing among the different species of the genus.

In *G. gnemon*, Madhulata (1960) has shown that a small tuber-like projection may be developed directly from one side of the zygote, or in some ovules the zygote divides forming a two-celled structure, each of which on germination gives rise to a short tube; frequently, only one of these two cells germinates. In rare cases, instead of a single tube, two or three tubes are developed from a zygote. The particular tube which receives the zygote-nucleus remains functional.

while the others become abortive. The tube containing the nucleus grows in a downward direction, pushes inside the endosperm, grows through intercellular spaces and finally gives rise to a number of elongated uninucleate cells by the formation of septa. This is the **primary suspensor tube** or **suspensor tube** or **proembryo tube.**

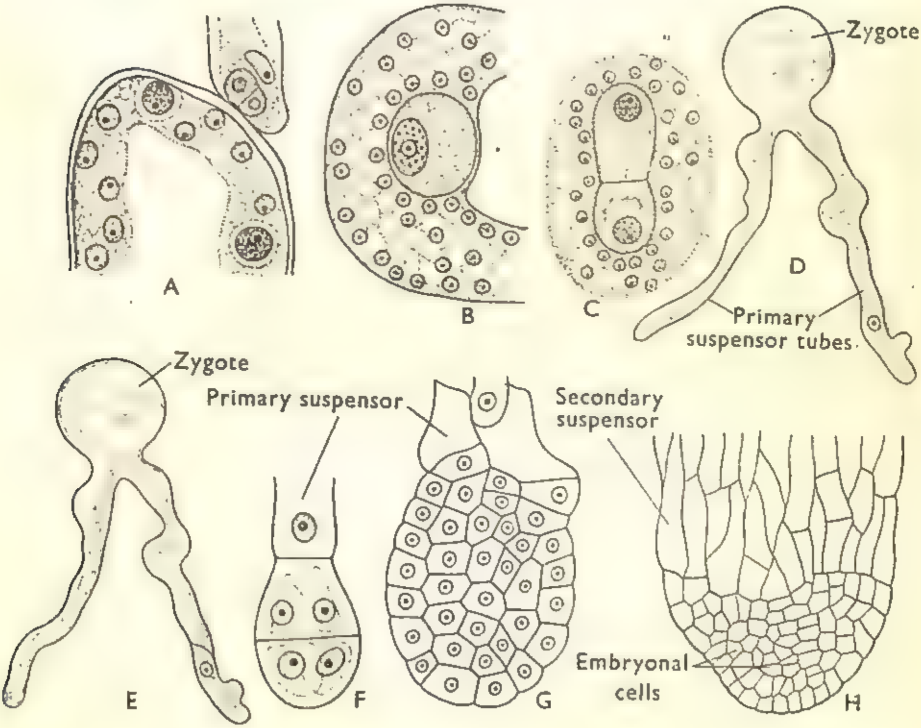


Fig. 472. *Gnetum.*
A—H, Stages in fertilization and development of new sporophyte.

Usually, a small protuberance appears either above or below a septum. This later on becomes elongated forming a more or less tube-like structure, into which passes a nucleus. Thus, the primary suspensor tube usually becomes much branched. After the formation of the primary suspensor tube is completed, a small cell is cut off at its tip which first divides transversely and then longitudinally to give rise to a tetrad of cells. From these apical cells by further divisions there appears a more or less globose mass of cells which constitute the **embryonal cells.** Sometimes the primary suspensor itself undergoes divisions. Of the group of embryonal cells, those which are

terminal in position develop into an **embryo,** while those which are situated behind the embryo become considerably elongated and divide further to give rise to a long **secondary suspensor.** This secondary suspensor helps in pushing the embryo deeper within the endosperm for obtaining better nutrition.

In some species, like *G. ula*, *G. gnemon* and others polyembryony is frequently met with, which may originate in several ways.

A mature seed is usually elongated but may be slightly oval also. Its colour varies from green to red. The endosperm is very conspicuous and remains enveloped by three envelopes. The cotyledons are two in number.

Economic Importance of the Gymnosperms

The members of the gymnosperms are utilized for various purposes. The chief uses of them are, however, as fuel, timber, lumber and materials for making building and furniture. Some of them are used for ceremonial decorations as well as ornamental garden plants. The tubers of the cycads yield the arrowroot starch. Some of the pines are sources of the pulp for the paper industry. Previously, the pine wood was employed in the preparation of match sticks. Some of the valuable pine products, which are obtained by distillation and other processes, are methyl alcohol, charcoal, resin, wood gas, turpentine, various kinds of oil and others. The bark of hemlock (*Tsuga canadensis*) gives tannins, which are extensively used for the purpose of tanning animal skins into leather, for making ink as well as for manufacturing drugs. *Pinus geradiana* and several others supply edible seeds. Amber, which is utilized for making ornaments and art curios, is nothing but the resin of a fossil pine. An important medicinal plant is *Ephedra*, from which is obtained the alkaloid 'ephedrine'. The inflorescence and young leaves of *G. gnemon* are taken as vegetables in some parts of South-East Asia. The seeds also are edible after cooking or roasting. From the bark is obtained a kind of fibre, which is used for making ropes, fishing nets, etc. In South India the seeds of *G. ula* are taken as food. The plant also possesses some properties detrimental to the fishes. The kernel of the seed of *G. latifolia* is also taken as a food after boiling or roasting. Its bark is also utilized for preparation of nets and ropes. The fossil gymnosperms, particularly the Pteridosperms, have contributed to a large extent to the formation of coal.

CHAPTER VII

ANGIOSPERMS

The Angiosperms or 'closed-seeded' plants are very complex seed-bearing plants (Spermatophytes). They include the great majority of seed-plants. The most distinguishing feature of this group is that the *carpels unite by their margins to form an ovary in which the ovules are enclosed*, and the *pollen grains fall upon a receptive surface known as the stigma.* The plant is the sporophyte which is more highly differentiated than those of the gymnosperms. As in gymnosperms, *the sporophylls are aggregated to form 'flowers' but they are provided with one or two accessory whorls.* The sporophyte is *always heterosporous* producing two kinds of spores. The micro- and mega-sporophylls are usually found in the same flower. As in gymnosperms, two kinds of gametophytes are produced but they are extremely reduced. *No organ corresponding to archegonium is found.* The reproduction is effected by motionless gametes. *The endosperm is produced after fertilization.* Seeds are enclosed within fruit.

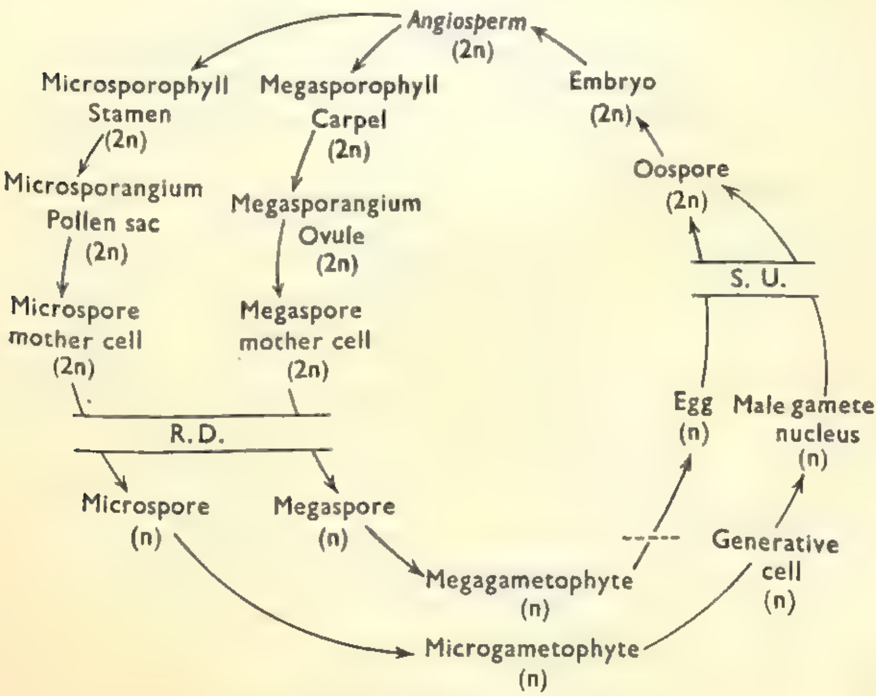


Fig. 473. Life cycle of Angiosperm.

In the angiosperms there is an 'alternation of generations' but it is very much less distinct. The plant itself is the sporophyte because it bears spores (e.g., microspores or pollen grains and megaspores) and it is more conspicuous of the two generations. The male gametophyte is represented by the pollen tube and the female gametophyte by the embryosac. The female organs or archegonia themselves have perished though their essential cells, the oospheres or eggs, have still persisted. It is to be noted that the gametophyte is completely dependent upon the sporophyte.

Origin of Angiosperms

The origin of the present-day angiosperms is a very knotty problem, and is not yet properly understood. The phylogenists have put forward some theories from time to time, a brief resume of some of which is presented below :

Though there is a lack of adequate palaeobotanical records, a large number of workers try to establish the origin of angiosperms from some gymnospermous stock or from some of their ancestral forms, and as such, angiosperms may be monophyletic or polyphyletic in origin. Arber and Parkin (1907) suggested a hypothetical connecting link in between the Cycadeoideae and the Angiospermae. They gave the name **Hemiangiospermae** to this link, whose imaginary reproductive organs were constructed as in the cycadeoid flower in having an elongated axis bearing spirally arranged perianth-leaves, the androecial branch of numerous stamens, and a large number of open carpels with marginal megasporangia. From such a type the magnoliaceous flower is supposed to have originated. According to this view, therefore, the angiosperms are monophyletic in origin, as all of them have come from the same ranalian stock; the dicotyledons have come first, and the monocotyledons constitute an offshoot of them. But there is no fossil record to prove that such a structure was ever present. It is interesting to note, however, that this theory was nevertheless accepted by workers like Bessey, Hutchinson, and others. Wettstein (1910-11) postulates that the ancient angiosperms were monosporangiate, and were derived from a gnetalian inflorescence. He regards *Casuarina* as the most primitive of the existing angiosperms. According to him, the bisexual flower came into existence by the appearance of a terminal pistillate flower on a staminate inflorescence. Markgraf (1930) also lays emphasis on the Gnetales for

providing a solution to this problem of angiosperm origin. Fagerlind (1947) considers that there was a common ancestral stock, which had given rise to a line, from which have originated the present-day *Gnetum*, *Ephedra*, and *Welwitschia* among the gymnosperms on one hand, and another in the other direction, from which have evolved the modern angiosperms polyphyletically; he terms the latter as the **Proangiosperms.** Andrews (1947), and Arnold (1947) are both of opinion that the angiosperms have come from the pteridosperms, but Darrah (1939) considers it to be an entirely debatable point. A few workers suggested that the angiosperms might have been evolved from the Caytoniales, a Jurassic group of angiosperm-like plants, recorded by Thomas (1925). But Arnold has shown that they are simply some Mesozoic remnants of the pteridosperms. Campbell (1925) rejects the idea of the derivation of angiosperms from the cycadeoidean stock, and suggests their origin from some pteridophytic ancestor. According to him, the monocotyledons are more primitive than the dicotyledons. Engler (1936), however, discredits both the cycadeoidean as well as the gnetalian theories of origin, and suggests that the monocotyledons and dicotyledons have arisen independently from a hypothetical group, called the **Protangiosperms,** existing in the Mesozoic. The Protangiosperms themselves might have come from some *Ophioglossum*-like eusporangiate pteridophytic stock, and bore flowers, which were bisporangiate and were either completely achlamydeous or were provided with a very rudimentary perianth. Rendle (1904) supports this idea of Engler.

A view quite different from the previous ones was expressed by Sahni (1920), and later on elaborated by Lam (1948). According to this theory, which is being known as the *Stachyosporous theory* of the origin of the angiosperms, the seed plants belong to two *taxa:* **Phyllospermae** and **Stachyosporae.** In the former, the megasporangia lie enclosed within leafy carpels and contain the majority of the apocarpous dicotyledonous plants and their derivatives. In the Stachysporae, on the other hand, the megasporangia remain covered by some sterile organ; this latter taxon comprises of the Monochlamydeae of Bentham and Hooker and "perhaps some monocotyledons and sympetalae".

Anderson (1934) suggests that the angiosperms might have been evolved as a result of hybridization between very widely different gymnosperms. Goldschimdt (1940) is also of opinion that the

evolution of the major angiospermic taxa might have taken place as a result of direct mutations.

THE MAIZE PLANT

(Zea mays)

The Maize is a monocotyledonous plant belonging to the family Gramineae.

It is an annual herbaceous plant of very varying heights. The plant has a fibrous root-system with three distinct types of roots: (1) **seminal roots** develop from the radicle and form the primary root-system, which may persist throughout the whole life of the plant and branch extensively or may die down; (2) **adventitious roots** are produced from the nodes near the ground level, branch vigorously, run almost parallel to the surface of the soil and finally penetrate into it; (3) **prop roots** are developed in whorls from some of the nodes above the ground level during the rapid elongation of the stem and these are generally much thicker than the former two types. After entering into the soil they function as ordinary roots.

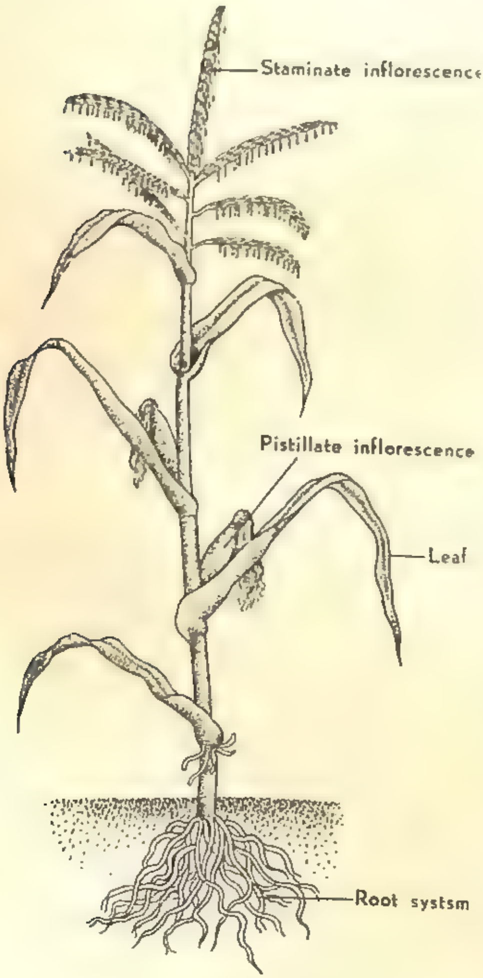


Fig. 474. Maize plant.

The stems are round, solid and jointed at the nodes.

The leaves are spirally arranged having a distichous phyllotaxy. They are simple and linear-lanceolate in shape with entire but slightly wavy margins and a sharp acute apex. The venation is of the parallel convergent type having a firm midrib with numerous smaller parallel veins running from the base to the apex, and these may be cross-connected by transverse veinlets. The surface may be glabrous or pubescent and is very slightly ribbed. The sheathing leaf-base encircles the internode for some distance above its place of origin and is split open on the side opposite to the lamina. Each mature leaf has a collar-like **ligule** at the junction of the lamina and the sheath. Numerous stomata occur on both the surfaces of the leaf.

The inflorescences

The plant is monoecious and diclinous, i.e., the staminate and pistillate flowers are produced on the same plant but on different

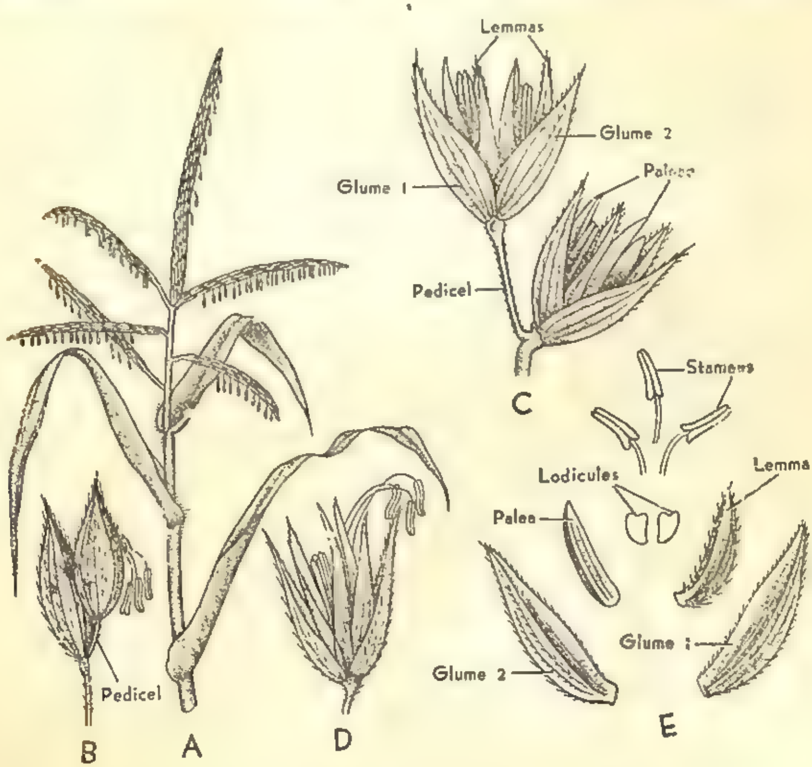


Fig. 475. Maize.
A, Staminate inflorescence; B, A 2-flowered male spikelet; C, Same enlarged (young); D, Same showing one mature flower; E, Dissected parts of D.

inflorescences. The former are borne terminally forming a panicle which is commonly known as the **tassel,** while the latter, popularly called the **ear,** develop on a short, thick and lateral branch produced in the axil of one of the lower leaves.

Staminate inflorescence. The central axis is continuous with the main axis of the stem and bears a variable number of lateral branches developed in a spiral manner. The flowers are borne in spikelets, arranged in rows of varying numbers of both the central axis as well as the lateral branches (the number of rows on the lateral ones is reduced only to two). Each row consists of a pair of spikelets, one of which is pedicellate and the other sessile.

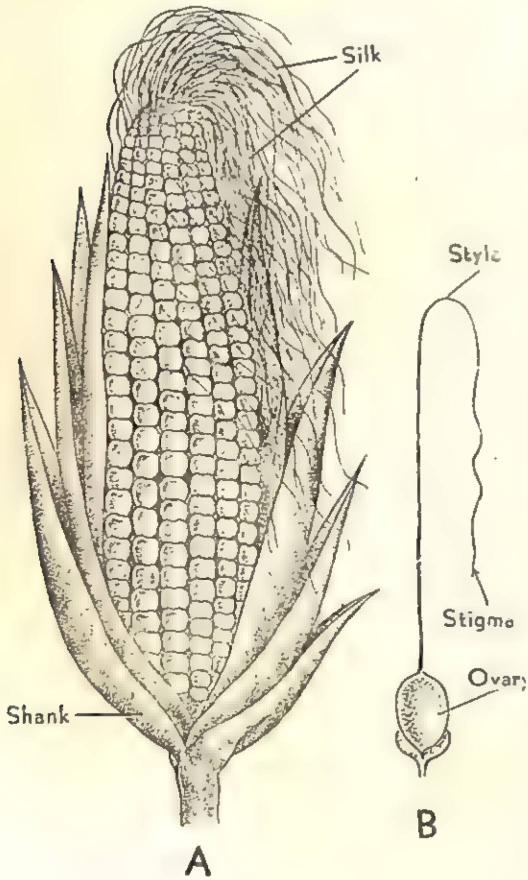


Fig. 476. Maize.
A, Pistillate inflorescence; B, A female flower.

Pistillate inflorescence. It consists of a short, thick, central axis, the **cob,** which bears a series of paired spikelets in longitudinal rows, varying from 2-15 or even more in number. It should be noted that the stalk of the cob (**shank**) is in reality a condensed shoot having compressed internodes, the uppermost one of which is the shortest. Small leaves appear from the nodes of the shank, excepting the one at the basal node, constitute the **husks** and protect the terminal ear. The leaves of the husks are closely overlapping one another and may possess blades and ligules.

The flowers

Staminate flower. Each staminate spikelet is a two-flowered one and subtends at the base a pair of glumes which completely enclose the two flowers while young. The two flowers are exactly identical but the upper one matures first. The two glumes are almost equal in size and thickly covered with stiff, sharp-pointed hairs; the outer or lower glume (**Glume 1**) is slightly overlapping the inner or upper one (**Glume 2**). Each flower has two bracts, the outer being called the **lemma** and the inner one the **palea,** inserted opposite to the lemma. At the base of the lemma and alternating with the stamens are the two fleshy **lodicules** which probably represent the perianth. During anthesis the lodicules enlarge considerably and push apart the glumes for an easy exit of the filaments. There are three stamens (two opposite to the lemma and one opposite to the palea) with versatile and two-lobed anthers, and long filaments. In each staminate flower there is a centrally placed rudimentary gynoecium.

Pistillate flower. Each pistillate spikelet is normally two-flowered, but the lower flower usually aborts. As in the staminate spikelet, the two glumes lie enclosed within a pair of glumes and each individual flower is subtended at the base by a lemma and a palea. The abortive flower has two lodicules, three rudimentary stamens and one rudimentary carpel, whereas in a mature fertile flower the lodicules are not easily recognizable, the rudimentary stamens also cannot be distinguished very clearly, while the carpel is very well-developed. The palea and the lemmas of both the flowers persist and constitute the **chaff** of the mature grain. It should be noted that though the gynoecium appears to be an apparently monocarpellary one, it is in reality tricarpellary, two of which extend to form the **silk** (the so-called hairy style), while the third one bears the campylotropous ovule.

Homogamy is of rare occurrence in maize, while dichogamy is the normal rule. The dichogamous flowers may be either protandrous or protogynous.

The gametophytes

Male gametophyte. The pollen grains are developed by the process of meiotic division (Vide General Botany) and are extremely light and dusty. Each pollen grain is almost spherical in outline and is provided with two usual coatings; the exine is very minutely

tuberculate and has a single conspicuous germ pore. The development of the male gametophyte begins with the division of the pollen nucleus into two parts—a **vegetative nucleus** and a **generative nucleus.** The latter then divides again and gives rise to two long crescent-shaped **male gamete nuclei.** The pollination takes place at this stage. A few hours after pollination, the pollen tube emerges through the germ pore and in course of 24 hours it may reach the embryosac. It is interesting to note that the older portion of the pollen tube may die away, while its apex enlarges considerably.

Female gametophyte. The mode of development of the female gametophyte very much resembles that of Pea. But the three antipodal nuclei soon after their orientation undergo several repeated divisions, finally giving rise to 24-36 uni- or bi-nucleate cells. In the meanwhile the synergids become elongated or rounded and in the majority of cases they disintegrate before fertilization. The ovum increases considerably and attains a width of about half that of the embryosac.

Fertilization is effected within 24-36 hours after pollination with the usual formation of the zygote and the primary endosperm nucleus (Vide General Botany).

The new sporophyte

After fertilization the primary endosperm nucleus undergoes

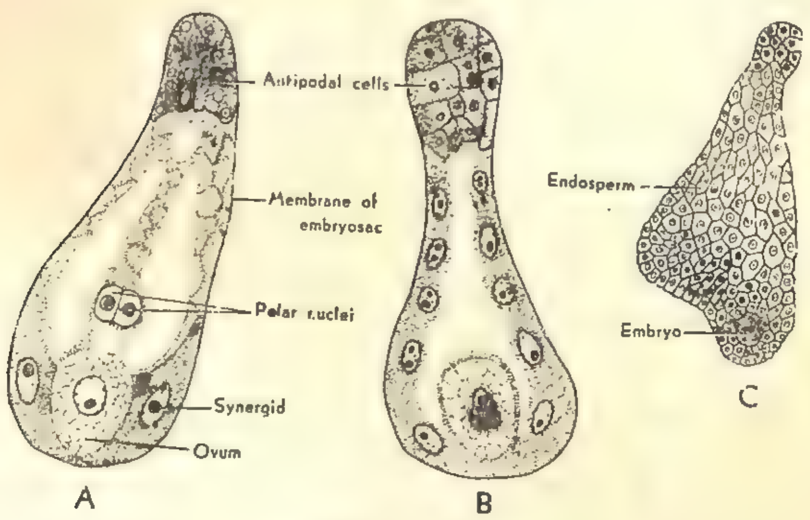


Fig. 477. Maize.
A—C, Successive stages in the formation of embryo and endosperm.

several free nuclear divisions immediately forming a number of nuclei. At this stage the zygote divides transversely into two unequal cells. The smaller upper cell by further divisions develops into a 3-4-celled proembryo in a very short time and the same becomes a 10-24-celled structure at the end of the fourth day. Meanwhile, the large basal cell also divides to form a massive suspensor which finally becomes twisted. At the end of the eighth day, due to continued growth of the apical region, the embryo becomes club-shaped. The plumule of the embryo differentiates out as an oblique protuberance from the proembryo about ten days after pollination. The initial of the scutellum (cotyledon) also appears as a lateral lobe. The radicle and the epicotyl differentiate out within ten to fourteen days of pollination, the suspensor grows considerably, and the

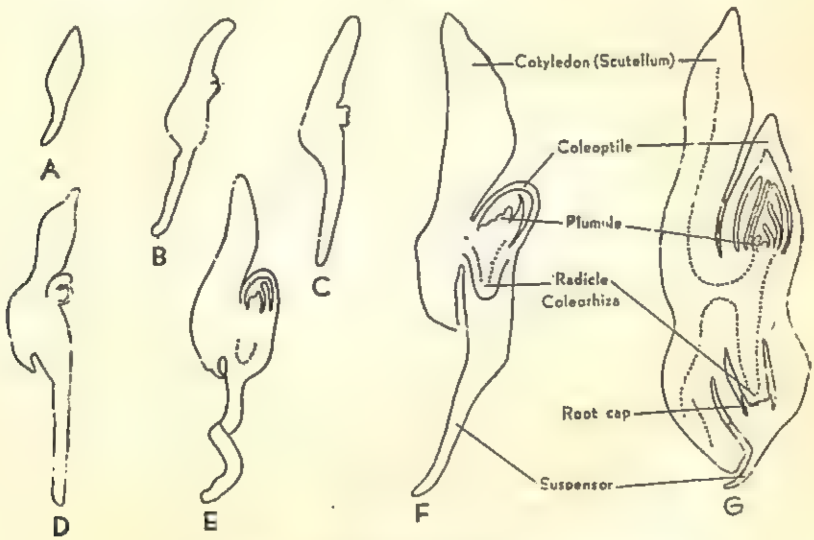


Fig. 478. Maize.
A—G, Successive stages in the development of embryo.

scutellum also enlarges and finally assumes an apparently terminal position. The growth of the suspensor comes to an end after about twenty days. The coleoptile and the first foliage leaves (usually five in number in a mature embryo) are developed in about a week's time following the formation of the radicle and the epicotyl. The coleoptile is at first a closed sheath enclosing the young foliage leaves. The radicle (developed from the lower end of the axis between the plumule and the suspensor) also remains enclosed within

the root-sheath or coleorhiza, which is produced as a result of the splitting away of the basal ground tissue from the upper one on account of unequal growth. Sometimes later a few (two to three) seminal roots are produced just above the cotyledonary node. At the end of about forty-five days the embryo becomes mature.

The embryo during its early stages of development remains almost completely embedded within the endosperm. About three days after pollination more than hundred nuclei (produced as a result of free nuclear divisions of the primary endosperm nucleus) are found to lie on the periphery of the embryosac. Very soon cell walls begin to appear centripetally and the embryosac becomes almost entirely cellular. Now food matters in the form of starch and proteins begin to be deposited within these developing tissue and the whole (excepting the developing embryo and the antipodals) becomes converted into the endosperm. In an almost mature endosperm, the outermost cells, by a series of periclinal divisions, form the aleurone layer. The antipodals retain their individuality for a considerable length of time and may even increase in number but ultimately they are destroyed by the developing endosperm and finally disappear when the grain is mature.

As a result of fertilization the ovary is converted into a fruit which is a caryopsis, in which the pericarp remains intimately fused up with the seed coat; the grain is endospermic.

A mature grain on germination gives rise to a new maize plant, the mode of germination being hypogeal (Vide General Botany).

THE PEA PLANT

(*Pisum sativum*)

The Pea is a dicotyledonous plant belonging to the subfamily Papilionaceae under the family Leguminosae.

It is an annual herbaceous climbing plant, often attaining a bushy habit, with lateral branches and a strong much-branched tap-root. On the roots are frequently found some nodular swellings, the **root tubercles;** these harbour the nodule bacteria (*Bacillus radicicola*) which help in the fixation of atmospheric nitrogen.

The stems are generally hollow, round, greenish in colour, glaucous and attain various heights.

The leaves are spirally arranged and pinnately compound with

their terminal leaflets along with a few of the upper lateral ones modified into tendrils. The leaflets are somewhat ovate in shape with entire margins and glaucous surfaces. The stipules are broad and foliaceous.

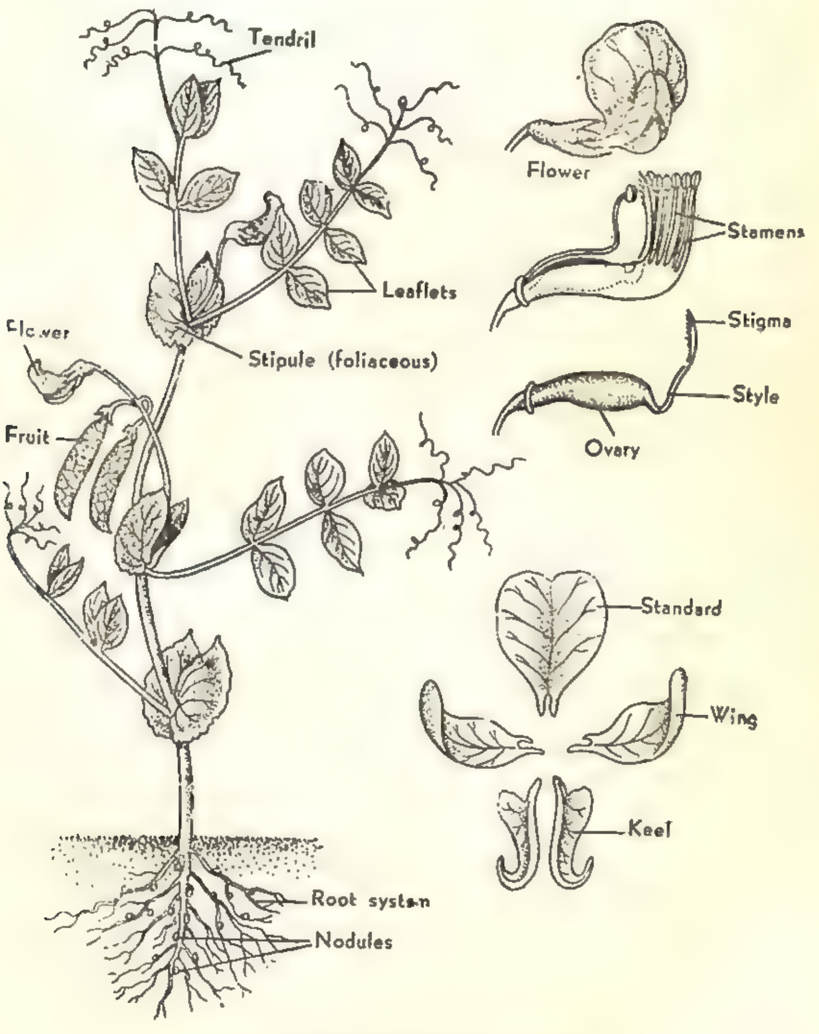


Fig. 479. Pea plant and its parts.

The inflorescence is an axillary raceme bearing flowers of various shades of colours ranging from pure white to deep blue, purple, lilac, rose, light green and so on.

The flower is complete, bisexual, irregular and zygomorphic.

The calyx-tube is slightly oblique and is composed of five, slightly unequal lobes; in some cases one of the lobes may be absent. The corolla is papilionaceous and consists of five petals of different sizes, of which the uppermost or the outermost one is called the **standard** or **vexillum,** which covers the other four in the bud stage (vexillary type of aestivation); the two lateral ones, extending obliquely outwards, form the **wings** or **alae,** while the two innermost or lowermost ones unite loosely along their ventral margins and constitute the **keel** or **carina.** The stamens are ten in number and diadelphous, the tenth free one being the uppermost. The gynoecium is monocarpellary and the green-coloured superior ovary is unilocular bearing two rows of ovules, developed upon marginal placentae borne on the dorsal suture ; there are actually two parallel rows of placentae but these lie so very close to each other that they may appear to lie in a single row. The style roughly forms a right angle with the ovary and the stigma is bearded on its inner face. The ovule is campylotropous.

The Pea plant, as a rule, is self-pollinated on account of the protandrous nature of the stamens; the anthers generally dehisce before the flower bud opens and the keel becomes filled with pollen grains. In a few cases, however, cross-pollination with the help of insects has been recorded.

The gametophytes

Male gametophyte. The pollen grains are developed from the pollen mother-cells by the process of meiotic divisions (Vide General Botany). Each pollen grain is provided with two coatings—an *exine* and an *intine*, with two germ pores on the former one. The pollen grain undergoes a division in the transverse plane and forms a **tube cell** and a smaller **generative cell.** After pollination, the intine bulges out through one of the germ pores in the form of a tube, known as the **pollen tube** (*male gametophyte*). The tube cell degenerates very early, while the generative cell undergoes another division forming two **male gametes,** each surrounded by a thin cytoplasmic layer and separated from the contents of the pollen tube by a delicate membrane.

Female gametophyte. Within the body of the nucellus, surrounded by the two integuments, there appears the megaspore mother-cell which by meiotic divisions gives rise to a linear tetrad of megaspores; the three upper ones degenerate leaving behind the

one (nearest the chalazal end) as the functional megaspore. The megaspore by the usual three successive nuclear divisions (Vide General Botany) produces an eight-celled **embryosac** (*female gametophyte*). A fully matured female gametophyte is slightly curved, elongated, eight-nucleate but seven-celled structure; of

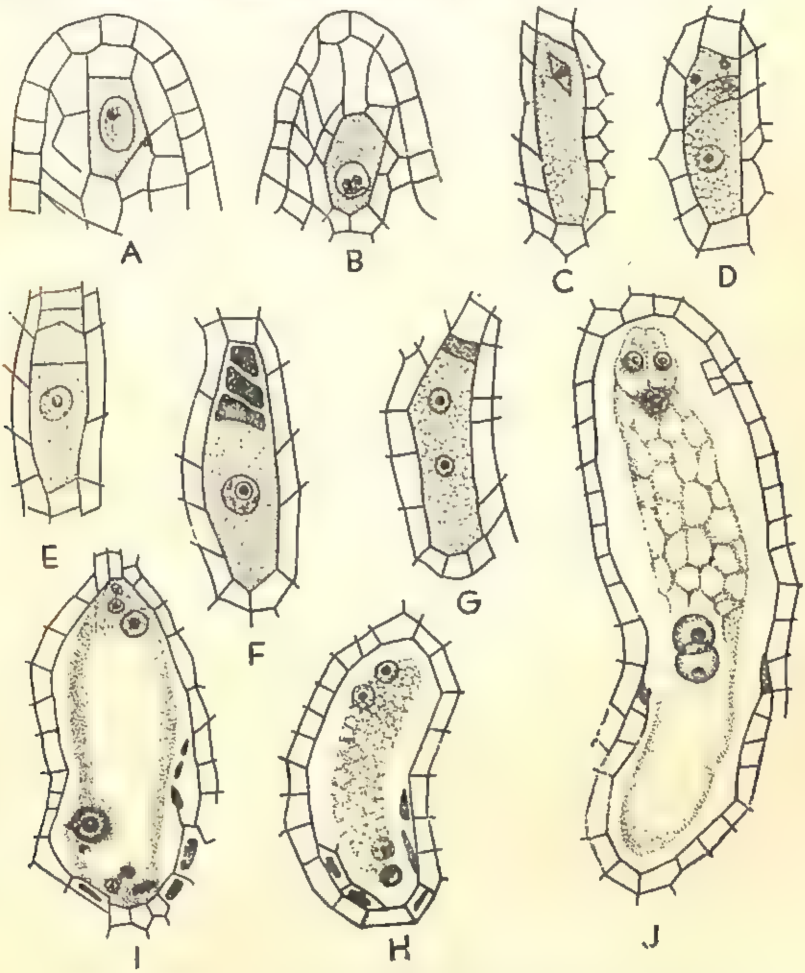


Fig. 480. Pea.
A—J, Successive stages in the development of female gametophyte.

these seven cells, three are situated towards the micropylar end of the ovule forming the **egg apparatus,** three at the chalazal end forming the **antipodals,** and the remaining two uniting at the centre but with their nuclei remaining distinct prior to the time of fertilization, when they unite giving rise to the **definitive** or **secondary nucleus.**

For the process of fertilization—Vide General Botany. It is to be noted that fertilization takes place about 12-14 hours prior to the opening of the flower bud.

The new sporophyte

The zygote, after fertilization, divides transversely and the endosperm at this stage may be two- or four-nucleate. Gradually, as the flower withers away, a 4-celled proembryo is produced, the upper two cells being arranged longitudinally while the lower two are placed side by side. The embryo develops from the terminal cell; the middle cell divides longitudinally and the daughter cells (thus produced) become much enlarged and multinucleate, and these along with the two highly elongated and multinucleate basal cells form the **suspensor.** It is to be noted that the development of the embryo begins to take place about 24 hours after pollination.

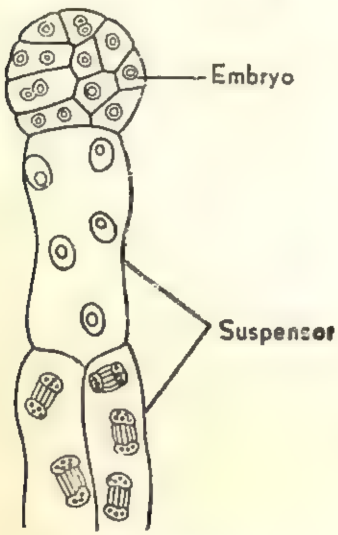


Fig. 481. Pea. Development of new sporophyte.

About 48-72 hours after pollination, the nucellus is completely used up by the developing embryo, which then begins to feed upon the inner integument as well as the starch-content present therein. Now the suspensor elongates considerably and the embryo is pushed towards the curved region of the embryosac, where its final development is completed. The inner integument is ultimately completely digested. The major portion of the embryosac is occupied by a somewhat sweet watery endosperm devoid of starch, and the embryo occupies a comparatively insignificant portion of the embryosac. The cotyledons differentiate out about 6 days after pollination, followed by the gradual degeneration of the suspensor. The endosperm may temporarily assume a cellular form and becomes completely exhausted when the seed is about 10-12 days old. A mature seed consists of the embryo and a solitary seed coat, which is produced from the outer integument.

As a result of fertilization the ovary is converted into a fruit which is a **legume,** and its wall is transformed into the pericarp; the ovules develop into mature non-endospermic seeds.

A seed on germination gives rise to a new Pea plant, the mode of germination being hypogeal (Vide General Botany).

Economic Importance of Angiosperms

Seeds. Of all the parts of the plant body, the seeds form the most important sources of staple food supply. The value of the three outstandingly important cereal crops, rice, wheat and maize, needs no introduction. Other important crops, providing food for both the human beings as well as cattle, are millet, barley, oat, sorghum, rye, etc. These are more or less cultivated all over the globe. Seeds of the leguminous plants have also very great economic importance. They give us pulses (lentils, peas, grams, etc.), soy beans, pea nuts, beans and others, all of which are rich sources of vegetable proteins. Various kinds of nuts, like walnut, chestnut, cashewnut, coconut, almond, etc., are also used for food. The coconut is also the source of copra, and from its dried meat an oil is extracted. Seeds of flax, linseed, tung-oil seed, cotton, etc., yield important oils used in the paint and varnish industries. Oils extracted from the seeds of mustard, coconut, linseed, groundnut, etc., are used for domestic purposes. Castor oil, from seeds of castor, is used in medicine as well as an engine-lubricant and a fuel. The seeds of *Taraktogenos kurzii* (Fam. Bixaceae) yield the famous chaul-moogra oil, which is extensively used in the treatments of leprosy and other cutaneous diseases. Coffee bean of commerce is obtained from the seeds of *Coffea arabica* (Fam. Rubiaceae), a plant widely cultivated in the tropical regions of the world. Various kinds of alcoholic drinks are usually prepared from the cereals. Seeds, like cotton, are very good sources of fibres which are not only used in the textile industry, but also provide important materials necessary in the manufacture of explosives, tyres, celluloid, rayon, cellophane, etc. Kapok seeds are used for stuffing pillows, mattresses and furniture. Some important dyes like anatto, used in dyeing and staining butter, are obtained from the seeds of *Bixa orelana* (Fam. Bixaceae). Sometimes the oils from the seeds of *Guizotia abyssinica* (Fam. Compositae), *Argemone mexicana* (Fam. Papaveraceae), *Bassia latifolia* (Fam. Sapotaceae), etc., are extensi-

vely used by unscrupulous dealers in adulterating edible oils and clarified butter. Jewellers use the red seeds of *Abrus precatorius* of subfamily Papilionaceae (Fam. Leguminosae) as small weights. Endosperm of the tropical American genus *Phytelephas* (Fam. Palmae) yields vegetable ivory.

Roots. Many economic products are obtained from the roots of plants. The tuberous roots, like sweet potato, carrot, turnip, beet, etc., form the important sources of human food. In many cultivated crops, as in sugar beet, which is a very important source of sugar, the root only is harvested. Some of them provide food for the cattle. Some roots contain high percentages of active chemical substances of great medicinal importance, as in Aconite (*Aconitum napellus*) of Fam. Ranunculaceae, Gentian (*Gentiana lutea*) of Fam. Gentianaceae, Ipeacac (*Psychotria ipecacuanha*) of Fam. Rubiaceae, Sarsaparilla (*Smilax macrophylla*) of Fam. Liliaceae and *Hemidesmus indicus* of Fam. Asclepiadaceae, Licorice (*Glycerhiza glabra*) of subfamily Papilionaceae (Fam. Luguminosae), Rhubarb (*Rheum officinalis*) of Fam. Polygonaceae, etc. From some of them effective insecticides, like pyrethrum powder (obtained from *Chrysanthemum cinerariaefolium* of Fam. Compositae) and rotenone powder are manufactured. Roots of a Russian dandelion (*Taraxacum koksaghyz*) of Fam. Compositae provide new sources of rubber.

Stems. The economic products obtained from the stems of plants cover a very wide range and serve many useful purposes. One of the most important foods derived from the stem is sugar, which is obtained from the sap of Sugarcane plant. All the underground stems serve as important human foods; the rhizomes of Turmeric (*Curcuma longa*) and Mango ginger (*Curcuma amada*) of Fam. Zingiberaceae are used as condiments, while those of Indian arrowroot (*Curcumma zedoaria*) yields an inferior kind of arrowroot. The various kinds of valuable timbers are stem-products. Ordinary wood, used as fuel, is also derived from the stem; this is also a source of cheap quality of paper. The stems of plants like Jute (*Corchorus capsularis* and *C. olitorius*) of Fam. Tiliaceae, Flax (*Linum usitatissimum*) of Fam. Linaceae, Hemp (*Hibiscus cannabinus*) of Fam. Malvaceae, etc., furnish us with fibres, utilized for manufacture of clothings, gunny bags and other commercial commodities. Various kinds of chemicals and dye-stuffs are obtained from the stems. Medicines like quinine are obtained from the bark of stems of *Cinchona officinalis*, *C. succirubra*, *C. ledgeriana* and *C. calisaya* of Fam. Rubiaceae. The

stem-tubers of *Cyperus rotundas* and *Scirpus grossus* of Fam. Cyperaceae as well as the rhizomes of Ginger (*Zingiber officinale*) of Fam. Zingiberaceae are also used in medicines. Cinnamon is a product of the stem-bark of *Cinnamomum zeylanicum* (Fam. Lauraceae). Rubber, latex and guttapercha are obtained by tapping stem of various plants. Gums, resins, balsams and their products are secretions of the stems. From the pith of Sago Palm (*Metroxylon rumphii* of Fam. Palmae) is obtained the sago of commerce.

Leaves. Leaves mainly provide important sources of food, fibres and medicines. The green leaves of Cabbage (*Brassica* sp.) of Fam. Cruciferae, *Rumex vesicarius* (Fam. Polygonaceae), Celery (*Apium graveolens*) of Fam. Umbelliferae, Lettuce (*Lactuca sativa*) of Fam. Compositae, *Amaranthus viridis* (Fam. Amaranthaceae), Spinach (*Spinacia oleracea*) and *Chenopodium album* of Fam. Chenopodiaceae, *Basella rubra* (Fam. Basellaceae), etc., are common vegetables. The fleshy scale leaves of onion, garlic, etc., are frequently used for cooking purposes. These leafy vegetables are very rich in their vitamin-contents and thus help in nutrition. The leaves of *Eragrostis cynosuroides* (Fam. Gramineae) are used by the Hindus in religious ceremonies. The juice of the leaves of *Eclipta alba*, *Widelia calendulacea* and *Calendula officinalis* of Fam. Compositae are used as a hair-tonic; those of the first-mentioned plant are also used in tattooing the skin. Many important fibres of commerce, like Manila hemp (*Musa textilis*) of Fam. Musaceae, Sisal hemp (*Agave sisalana*) of Fam. Amaryllidaceae and Newzealand hemp (*Phormium tenax*) of Fam. Liliaceae, are obtained from the leaves. These fibres are chiefly meant for making twine, rope, etc. Quite a good number of important drugs and narcotics are also obtained from the leaves. For example, the leaves of *Erythroxylon coca* of Fam. Erythroxylaceae yield cocaine, those of *Cannabis sativa* of Fam. Moraceae provide hemp, etc.; tobacco is obtained from the leaves of *Nicotiana tabacum* (Fam. Solanaceae). Important drugs, like digitalis from *Digitalis purpurea* (Fam. Scrophulariaceae), stramonium from *Datura stramonium* and belladona from *Atropa belladona* (Fam. Solanaceae), etc., are also leaf-products. Leaves of *Swertia chirata* (Fam. Gentianaceae), *Corchorus acutangularis* (Fam. Tiliaceae), *Eupatorium ayapana* (Fam. Compositae), *Adhatoda vasica* and *Andrographis paniculata* of Fam. Acanthaceae, *Vitis setosa* of Fam. Vitaceae, *Paederia foetida* (Fam. Rubiaceae), *Herpestis monnieria* (Fam. Scrophulariaceae), *Hydrocotyle asiatica* (Fam. Umbelliferae), *Ocimum*

sanctum (Fam. Labiatae), etc., are extensively used in India as specific medicines. Leaves of *Phoenix paludosa* and *Nipa fruticans* of Fam. Palmae, *Typha angustata* (Fam. Typhaceae), etc., are used for thatching, and those of *Saccharum spontaneum* (Fam. Gramineae) are used as a substitute for straw-thatching. The universal beverage tea is obtained from the leaves of *Thea chinensis* of Fam. Theaceae, cultivated extensively in India, Ceylon, China and Japan.

Flowers. In most cases flowers have got only aesthetic value and as such are cultivated purely for ornamental, festive and decorative purposes. The Hindus use them extensively in their worships. Flowers like rose, jasmine, lavender, orange, carnation, etc., yield very valuable perfumes which are obtained by the distillation of the fragrant oils present in the blossoms. The flowers of Hops (*Humulus lupulus*) of Fam. Moraceae and *Bassia latifolia* (Fam. Sapotaceae) are cultivated for the manufacture of beverages. Flowers, such as lotus, orange, etc., are important sources of honey, which is derived from their nectar-secretions and kept in store by bees. The edible parts of some vegetable crops like cauliflower and broccoli (both belonging to Fam. Cruciferae) are nothing but huge clusters of abortive flower-buds. The flowers of *Sesbania*, gourd, horse radish, etc., are usually fried and taken as food. The dried unopened flower buds of Clove (*Eugenia caryophyllata*) of Fam. Myrtaceae have great commercial importance. The flowers of *Fuchsia* (Fam. Onagraceae) yield fuchsine, a red colouring matter much used as a staining reagent.

Fruits. The majority of the common fruits are usually taken in a raw state. These form very valuable diets and are important sources of vitamins, as in apple, pear, orange, lemon, grape, mango, banana, papaw, pineapple, etc. Quite a good number of fruits are used in cooked or pickled form, such as squash, gourd, cucumber, tomato, chillie, etc. A kind of flour is obtained from the bread fruits (*Artocarpus indica*) of Fam. Moraceae. The fruits of Olive (*Olea europea*) of Fam. Oleaceae is the source of the widely used olive oil. The dried fruit of Vegetable sponge (*Luffa aegyptiaca*) of Fam. Cucurbitaceae is used as a bath sponge or an oil-filter; it also yields an important kind of fibre. From the fibrous mesocarp of Coconut (*Cocos nucifera* of Fam. Palmae) mattresses and ropes are prepared. The latex of unripe fruits of Opium Poppy (*Papaver somniferum*) of Fam. Papaveraceae yields the powerful narcotic opium, used by the physicians as a sedative in forms of morphine

and codeine. The latex of the unripe fruits of Papaw (*Carica papaya*) of Fam. Caricaceae possesses a digestive property and is often used to make meat tender in cooking. The viscid mucous of the fruits *Diospyros embryopteris* (Fam. Ebenaceae) is used for making the bottoms of boats as well as fishing nets water-tight. The juice of the fruit of Marking nut (*Semecarpus anacardium*) of Fam. Anacardiaceae is used by washermen for marking clothes. The fruit of *Vanilla planifolia* (Fam. Orchidaceae), furnishes commercial vanilla, used in the preparation of cold drinks and chocolates.

CHAPTER VIII

MONOCOTYLEDONS

These are plants which bear only one cotyledon in their embryo. The radicle on germination produces a number of adventitious roots. Leaves have parallel venation and sheathing leaf-bases. Flowers are usually trimerous. Vascular bundles of the stem are closed and scattered in the ground tissue, and those of root polyarch.

ORDER 1. PANDANALES

Marsh-herbs, shrubs or trees, monoecious or dioecious; leaves linear; flowers unisexual, naked; or with a simple inconspicuous perianth; stamens 1-many; carpels 1 to many; fruit more or less nut-like; seeds rich in endosperm.

According to Engler's system of classification this Order has been placed at the beginning of the monocotyledons and comprises three families, viz., Typhaceae*, Pandanaceae* and Sparganiaceae. Bentham and Hooker have put the first two families under the series Nudiflorae. Hutchinson, however, has separated Pandanaceae from Typhaceae and Sparganiace, and has put it under the Order Pandanales. The aforesaid three families are now regarded to be simple by a reduction of reproductive organs and believed to have been derived from liliaceous stocks.

TYPHACEAE

General characters

Plants—perennial herbs of marshy places, monoecious; stem rhizomatous and creeping. Leaves—alternate, 2-ranked, *erect*, *very long* and *linear*, sessile with sheathing leaf-base. Inflorescence—dense cylindric spike (*spadix*). Flowers—minute, unisexual, hypogynous, naked; the male flowers are situated on the upper portion of the spadix and the female ones on the lower portion; both kinds of flowers are subtended by one caducous bact-like spathe. Perianth—represented by bristles. Stamens—in male flowers usually 3, monadelphous. Carpels—in the female flowers one; ovary superior,

situated on a gynophore, 1-celled with 1 pendulous ovule; style 1, persistent; many silky hairs present at the base of the gynophore. Fruit—a minute nutlet. Seed—albuminous with a straight embryo.

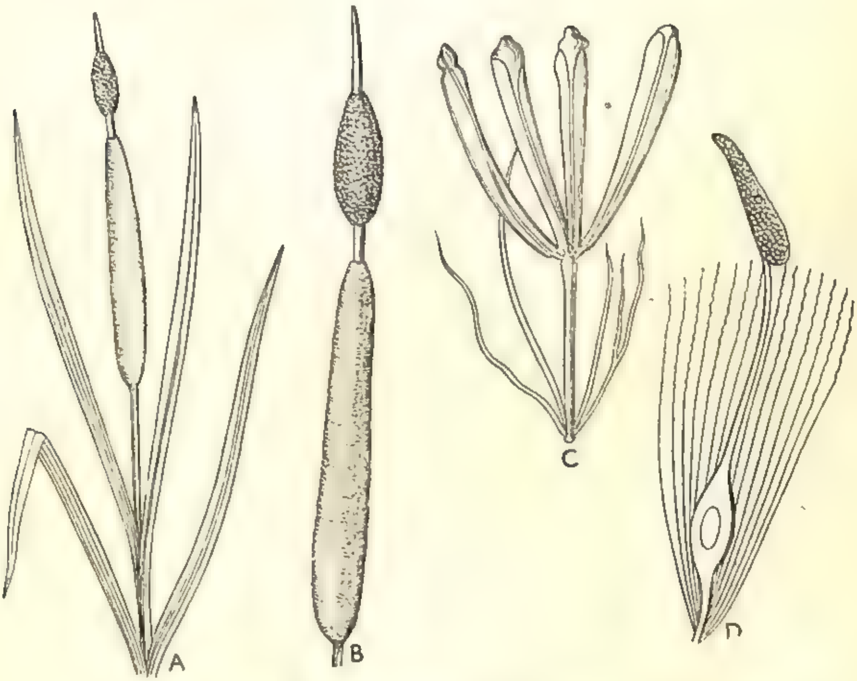


Fig. 482. Typhaceae (*Typha angustata*).
A, Portion of a flowering shoot; B, Inflorescence; C, Staminate flower; D, Pistillate flower.

Number and distribution

This family contains a single genus *Typha* with about 15 species. The genus is of cosmopolitan distribution throughout the marshes of temperate and tropical countries of both the hemispheres.

Common plants

(1) Bulrush (*Typha elephantina* and *T. angustata*), (2) *T. latifolia*, (3) *T. angustata*.

Affinity

This is the most primitive family of the monocotyledons. It is readily distinguished by its very long erect linear leaves, and dense spicate inflorescence (spadix), which is fuzzy brown at maturity.

Economic importance

This family is of little economic importance. The leaves of *T. elephantina* are often woven in making mats and screens, and for thatching temporary sheds. The pollens of *T. angustata* are often made into cakes which are taken by the poor people.

PANDANACEAE

General characters

Plants—often branched *palm-like trees* or shrubs, sometimes root-climbers, dioecious; usually with stout, stilt roots. Leaves—spirally arranged in crowns, simple, long and narrow having

Fig. 483. Pandanaceae (*Pandanus fascicularis*).
A, Plant; B, An inflorescence; C, Staminate flowers; D. A single staminate flower cut open.

spines along the margins and the midrib, sessile with sheathing leaf-base. Inflorescence—spadix, enclosed in a spathe-like bract. Flowers—small, unisexual. Perianth—rudimentary or absent. Stamens—in male flowers numerous; filaments distinct or united; anthers basifixed, dehiscing longitudinally. Carpels—in female flowers, numerous; ovary superior, 1-celled with 1-infinite anatropous

ovules; stigma as many as the carpels, sessile. Fruit—*drupaceous* or woody. Seed—albuminous (oil present) with basal small embryo.

Number and distribution

This family consists of 3 genera with about 300 species and occurs in the tropics.

Common plants

(1) The Screw-pine (*Pandanus fascicularis* L.), a small tree 10-12 ft. high, very common in Sundribans. (2) *P. foetida* Roxb., a bush with no proper stem, common in village thickets and hedges.

Affinity

This family is closely allied to Typhaceae in the reduction of flowers and spathe-formation, but is readily distinguished by its woody palm-like habit and nature of fruit.

Economic importance

This family is of little economic importance. Leaves are used for thatching, matting, clothing and making assorted containers. Fruits of some species are a source of food. Sometimes the plants are cultivated as ornamentals.

ORDER 2. HELOBIEAE

Plants mostly of aquatic or marshy habitats, often almost completely submerged; flowers unisexual or bisexual, regular, naked or with a simple or double perianth; stamens 1-many; carpels 1-many, superior and free, or inferior; seed exalbuminous containing a large embryo.

According to Engler this Order comprises 7 families, viz. Potamogetonaceae, Najadaceae, Aponogetonaceae, Scheuchzariaceae, Alismataceae*, Butomaceae and Hydrocharitaceae*. There is no mention of this Order in the Bentham and Hooker system. Alismataceae is, however, has been put under the series Apocarpeae.

ALISMATACEAE

General characters

Plants—perennial or annual *aquatic or marshy herbs*, with generally a stout rhizome, monoecious or polygamous. Leaves—radical or

clustered at the nodes, entire with broad petioles, sagittate or hastate. Inflorescence—*panicle* or *raceme* or *cymose umbel on scape.* Flowers—regular, bisexual (but unisexual in *Sagittaria*), bracteate, hypogynous. Perianth—3+3, free, *outer* 3 *sepaliod* and inner 3 petaloid, free, imbricate. Stamens—6-many. Carpels—3-6 or more, *apocarpous*; ovary superior, 1-celled with 1 or *more basal* anatropous ovules; placentation marginal or superficial. Fruit—*etaerio of achenes*, rarely of follicles. Seeds—minute, *exalbuminous.* Embryo—large, straight or curved.

Number and distribution

This family consists of 14 genera and about 55-60 species which are hydrophilous in habit and are confined to the temperate and warmer regions.

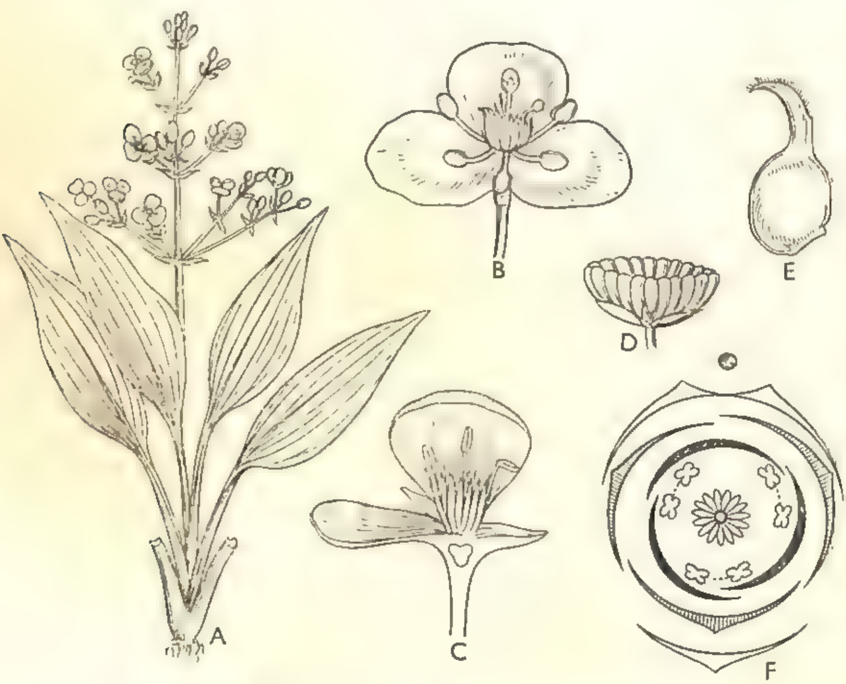


Fig. 484. Alismataceae (*Alisma plantago*).
A, The plant; B, Flower; C, The same with a perianth lobe removed; D, Fruit; E, Pistil; F, Floral diagram.

Key to Genera

A. Fls. hermaphrodite

(*a*) Fruit dehiscent of 6-7 follicles; stamens 8-12; ovules many .. .. *Butomopsis.*

(*b*) Fruit indehiscent of 3 or more achenes; stamens 6-9; receptacle flat ; ovule solitary .. .. *Alisma*.

B. Fls. polygamous ; fruit indehiscent

(*a*) Unisexual fls.; receptacle globose: stamens 6-many .. *Sagittaria*.

(*b*) Bisexual fls.; receptacle flat; stamens 6, 2-seriate .. *Limnophyton*.

Common plants

(1) Water plantain (*Alisma plantago* L.), a common water plant. (2) Arrowhead (*Sagittaria sagittifolia* L.), commonly found in tanks with sagittate leaves. (3) *Butomopsis lanceolata* Kunth. = *Tenagocharis lanceolata* Kunth., a common herb of marshes and rice fields with lanceolate leaves, milky juice and bisexual flowers. (4) *Limnophyton obtusifolium* Miq., another common water plant.

Affinity

This family closely resembles Ranunculaceae (in having hypogynous flowers with free sepals, petals and numerous stamens and carpels, and also in etaerio of achenes or follicles) and Commelinaceae, but readily distinguished by the aquatic habit, form of

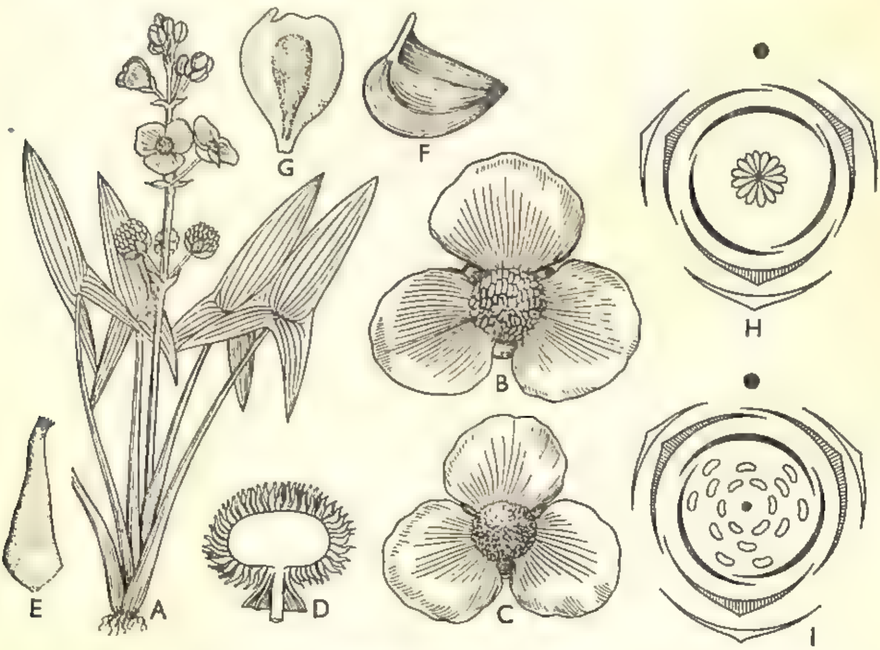


Fig. 485. Alismataceae (*Sagittaria sagittifolia*).
A, Plant; B, Staminate flower; C, Pistillate flower; D, V.s. of the same; E, Pistil; F, Fruit; G, V.s. of the same; H, Floral diagram of pistillate flower; I, The same of staminate flower.

inflorescence, two whorls of perianth and exalbuminous seeds. This does not necessarily indicate an affinity. It has been compared to Nymphaeaceae on account of superficial placentation but there is hardly any relationship between them. It differs from Hydrocharitaceae in the ovary having 1 or more basal ovules and the flowers usually arranged in whorls.

Economic importance

This family is of little economic importance. Rhizomes of *Sagittaria* are often eaten as an article of food by the Red Indians. The cultivation of Asiatic species is adopted by the Chinese people for their greater food value. Some plants are used as ornamentals, such as, *Alisma* and *Sagittaria*.

HYDROCHARITACEAE

General characters

Plants—floating or submerged aquatic herbs, dioecious, some-

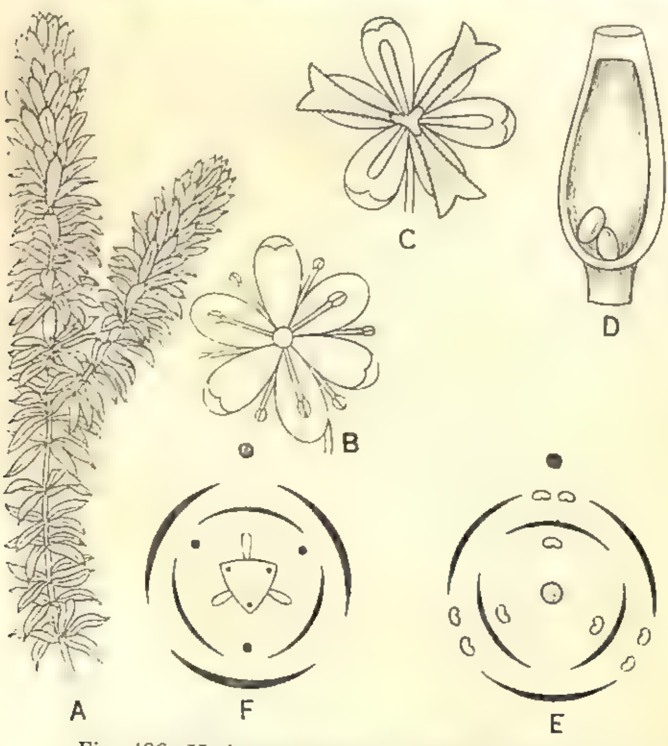


Fig. 486. Hydrocharitaceae (*Elodea canadensis*).
A, Portion of a plant; B, Staminate flower; C, Pistillate flower; D, L.s. of ovary; E, Floral diagram of staminate flower; F, Same of pistillate flower.

times monoecious. Leaves—radical or cauline (alternate, opposite or whorled), sessile. Inflorescence—umbel. Flowers—enclosed in an entire or 2-leaved spathe, regular, unisexual (sometimes bisexual e.g., *Ottelia*), epigynous. Perianth—3+3, generally distinguished into calyx and corolla, or 3 (e.g., *Vallisneria*), valvate. Stamens—in male flowers 3-12, but 9 in *Elodea* and 3 in *Hydrilla*. Carpels—in female flowers usually one; ovary inferior, 1-celled with numerous ovules on parietal placenta. Fruit—berry-like. Seed—exalbuminous containing a large embryo.

Number and distribution

This family consists of 16 genera with 80-90 species; 13 occurs in fresh water and 3 in the sea.

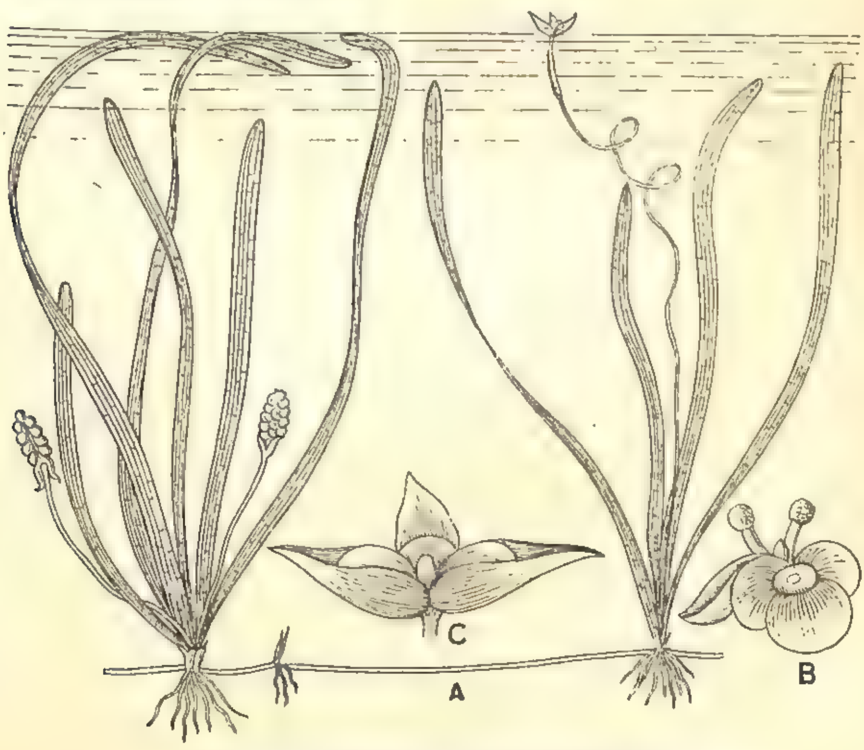


Fig. 487. Hydrocharitaceae (*Vallisneria spiralis*).
A, Portion of a plant; B, Staminate flower; C, Pistillate flower.

KEY TO GENERA

A. Stems branching, leafy; leaves small: spathes small, sessile:
  (*a*) Leaves whorled; styles undivided; ovules anatropous .. *Hydrilla*.
  (*b*) Leaves scattered; styles cleft; ovules orthotropous .. *Lagerosiphon*.

B. Stems none, or with stolons only, or a creeping rootstock
- (*a*) Leaves all long or narrow, sessile; male scapes several flowered—
  - (*i*) Perianth single .. .. .. *Vallisneria.*
  - (*ii*) Perianth double .. .. .. *Blyxa.*
- (*b*) Leaves mostly or all petioled—
  - (*i*) Ovary not beaked; fruit not winged; leaves all petioled; male scapes several flowered .. *Hydrocharis.*
  - (*ii*) Ovary beaked; fruit winged; submerged leaves narrow, others long-petioled; fls. solitary .. *Ottelia*

Common plants

(1) *Hydrilla verticillata* Casp., a submerged, leafy dioecious herb. (2) *Lagerosiphon roxburghii* L., a filiform tank herb. (3) *Vallisneria spiralis* L., a submerged, stoloniferous, dioecious herb. (4) *Blyxa roxburghii* Rich., a submerged, tufted, aquatic annual. (5) *Hydrocharis morsusramae*, a floating monoecious herb. (6) *Ottelia alismoides* Pers., a marsh herb with white flowers and ovoid fruits enclosed in a 6-winged spathe. (7) *Elodea canadensis* Michx., very common in ponds.

Affinity

The Hydrocharitaceae are considered to be closely related to the Butomaceae and differ from the latter by the presence of inferior ovary, the spathe or paired floral bracts and the monocarpellary pistil. Miki (1937) has opined that Hydrocharitaceae may be regarded as the ancestor of Najadaceae due to presence of inferior ovary in the latter. Uhl suggested that the genus *Najas* had no inferior ovary so he could not support the view of Miki. There is doubt whether the Hydrocharitaceae with well-developed perianth and multicarpellate parietal placentation is related to Butomaceae and Alismataceae complex as assumed by Uhl.

ORDER 4. GLUMIFLORAE

Annual or perennial herbs, sometimes arborescent, as in Bamboos; flowers small, naked or with a perianth represented by scales or hair-like structures; stamens usually in one whorl of 3; carpels 2-3; ovary superior bearing 1-3 styles; fruit a caryopsis or achene; seed with copious endosperm and a minute embryo.

According to Engler this Order comprises two families, viz., Gramineae* and Cyperaceae*. Bentham and Hooker have placed

the two families under the last series Glumiferae. Hutchinson places the two families in separate orders, Graninales and Cyperales respectively under the division Glumiflorae.

GRAMINEAE

General characters

Plants—mostly perennial, sometimes annual or biennial herbs, rarely arborescent (e.g., Bamboo). Stem—*cylindrical*, generally *fistular*, i.e., solid at the nodes and hollow in the internodes, rarely solid throughout (e.g., Maize, Sugarcane, etc.). Leaves—alternate, 2-ranked, linear to lanceolate,

Fig. 488. Grass spikelet (*Diagrammatic*) g_1, g_2, Empty glumes; g_3, Flowering glume; *p*, Palea; *l*, Lodicule.

Fig. 489. Gramineae (*Oryza sativa*). A, Portion of a flowering shoot; B, Flower; C, The same dissected out; D, Floral diagram.

with leaf-sheath which is *usually split up*, rarely closed, and *with a ligule* at the junction of the sheath and blade (but eligulate in *Echinochloa*). Inflorescence—spikelet, each spikelet is enclosed at the base by two glumes, known as *empty glumes*, one placed a little above the other. Flowers—usually bisexual, sometimes unisexual (e.g., Maize), sessile; each flower arises in the axil of a *flowering glume* or lemma*, which, encloses it at the base and a 2-nerved glume, called *palea*, placed opposite the flowering glume. Perianth—represented by 2 or 3 minute scales called *lodicules*†.

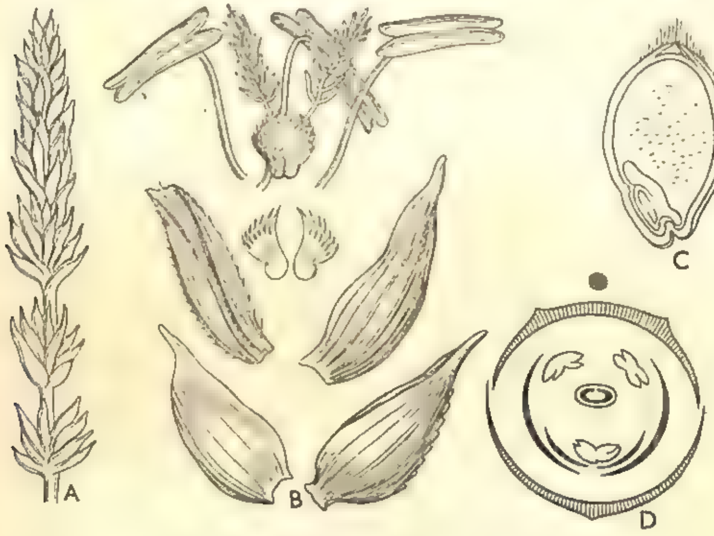


Fig. 490. Gramineae (*Triticum sativum*).
A, Portion of the inflorescence; B, Flower dissected out; C, L.s. of grain; D, Floral diagram.

placed within the palea. Stamens—either in one whorl of 3, or in two alternating trimerous whorls (e.g., Paddy and Bamboo), rarely in two alternating dimerous whorls or numerous; anthers *versatile*. Carpel—solitary, opposite the palea; ovary superior, 1-celled with a single erect anatropous ovule; stigma usually 2, lateral and feathery. Fruit—*caryopsis*, rarely an utricle. Embryo—placed at the base of the seed and *outside the endosperm*.

*The flowering glume, often bears an awn which may be attached to the apex (*terminal awn*) or to the back (*dorsal awn*), which aid both in the distribution of the fruit and also in fixing it to the soil.

†The lodicules separate the palea and the glume to allow the stamens and stigmas to protrude out of flower by virtue of the swelling and consequent pressure upon the bracts.

Number and distribution

This family consists of about 500 genera and 4,000 species which are cosmopolitan.

KEY TO GENERA

A. Herbs, flowers not dioecious:

(*a*) Spikelets 2-flowered, upper bisexual, lower male or neuter—

Mature spikelets surrounded by an involucre of bristles which falls off along with the spikelets .. .. *Pennisetum.*

Spikelets subtended by an involucre of bristles .. *Setaria.*

Spikelets not subtended by bristles; large grass; stem solid; leaves broad, flat .. .. .. *Thysanolaena.*

Slender grasses, stems creeping below, branching; leaves ovate-lanceolate, thin, flat; ligules a ridge of long hairs .. .. *Oplismenus.*

Annual or perennial grasses; leaves broad or narrow, flat, or rarely plicate; ligules *O* or hairy; glume II not fimbriate, glume III with a palea or quite empty .. .. *Panicum.*

Annual or perennial grasses; flowers (spikelets) in digitate spikes; lowest glume minute but usually present; glume III with a minute palea .. *Digitaria*

(*b*) Spikelets 1-flowered

(*i*) Spikelets articulated on their pedicels and deciduous from them—

Glumes I, II minute .. .. .. *Oryza*

Floating grass, diffusely branched, rooting in dense masses at the nodes; glumes I and II absent .. .. *Hygroryza.*

(*ii*) Spikelets usually in pairs—

Spikelets all similar—

Racemes of spikelets in compound panicles—

Panicle spiciform, silky, rachis tough; erect perennial grasses, stem leafy, internode solid, leaves narrow .. .. .. *Imperata.*

Panicle much-branched, silky, rachis fragile, spikelets awnless; tall perennial grasses .. .. *Saccharum.*

Spikelets dissimilar—

Spikelets in alternating pairs or the lower solitary—

Sessile spikelet usually many, inflorescence long .. *Andropogon.*

(*iii*) Male and female spikelets in different spikes—

Fruiting spikelets crowded on a spongy rachis, the grain exposed; a tall annual cultivated grass .. *Zea.*

Fruiting spikelet enclosed in the stony polished nut-like bract .. .. .. *Coix.*

(*c*) Spikelets 2- or more-flowered; annual or perennial cultivated grasses; leaves flat; spikelet with twisted awns .. .. *Avena.*

(*d*) Spikelets 3-7-flowered, in decompound panicles; tall perennial grasses with long leaves .. .. *Phragmites.*

(*e*) Spikelets many-flowered, not pedicellate, with long silky hairs; outer glumes shorter than the lowest flowering glume; grain very minute; annual or perennial glabrous grasses, stems erect, leaves narrow .. *Eragrostis.*

(*f*) Spikelets 2-seriate and secund—

Spikelets not clustered, 1-flowered, awnless, spikes digitate; perennial creeping grasses, leaves narrow, flat .. .. *Cynodon.*

(*g*) Spikelets 3-12-flowered in numerous digitate or whorled spikes .. .. *Eleusine.*

(*h*) Spikelets inserted in notches or pits of a simple rachis—

Spikelets solitary at the nodes of the spikes; plane of spikelets tangential to the rachis; annual or biennial cultivated grass .. .. .. *Triticum.*

Spikelets 2 or more, collected in fascicles at the nodes of the spikes; an annual cultivated grass .. *Hordeum.*

B. Shrubs or trees, rarely climbing; stem-sheaths broad, blade often triangular; leaves short-petioled .. .. *Bambusa.*

Range of floral structures

There may be one flower in a spikelet, as in *Agrostis*, 2 to many, as in *Arrhenatherum*, *Bambusa*, *Festuca*. The rachilla may or may not be continued beyond the flower. Thus, in many 1-flowered spikelets the flower is terminal, i.e., barren glumes, fertile glumes and palea are on the same axis (e.g., *Anthoxanthum*, *Agrostis*, *Oryza* and Andropogoneae). On the other hand, in *Gastridium* the solitary flower is lateral—the rachilla being produced beyond it. The lower barren glumes are rarely absent, as in *Coleanthus*. *Luveria* is distinguished from *Oryza* by their almost complete abortion. In *Brachiaria* (American genus), there is but one barren glume, generally there are two, sometimes more than 2, as in *Anthoxanthum*.

The empty glumes may closely resemble flowering ones, as in *Poa, Festuca*, etc., or be different in form, as in *Avena*, where they are much larger and envelope the rest of the several-flowered spikelets. In *Oryza*, they are less than half the length of the single-flowered spikelets. *Stipa* and some *Bambusa* have a third posterior lodicule, the perianth accordingly form a trimerous whorl. In *Melica*, there is only one lodicule.

In the great majority of cases there are 3 stamens. Only one stamen is present in *Uniola;* this is generally the anterior one, which on the contrary is suppressed in *Coleanthus* and the androecium becomes diandrous with 2 lateral stamens; in *Anthoxanthum*, the 2 stamens are antero-posterior. Most of the Bambusae and some *Oryza* have two alternate trimerous whorls (i.e., 6 stamens). In *Microlaena*, there are two alternating dimerous whorls (i.e., 4 stamens). There are rarely more than 6 stamens. *Pariana*, a tropical South American genus, with unisexual flowers has 10-40 stamens in the male flower and *Ochlandra* has large 1-flowered spikelet with 3-7 empty glumes, numerous lodicules and 6-30 polyadelphous or monadelphous stamens.

The ovary bears 1-3 styles, each terminating in a long densely papillate stigma, which is rarely simple but generally plumosely branched. *Nardus* has a single simple style and stigma. *Zea mays* has a single stigma formed by the union of 2. In the great majority of cases there are 2 styles. Many Bamboos have a third style. The solitary ovule is sessile on the ventral surface.

Common plants

(1) Paddy (*Oryza sativa* L.). (2) Wheat (*Triticum sativum* Lam.). (3) Barley (*Hordeum vulgare* L.). (4) Oat (*Avena sativa* L.). (5) Maize or Indian corn (*Zea mays* L.). (6) *Pennisetum typhoideum* Rich., *P. typhoides* Staff & C. E. Hubb. (7) *Panicum frumentaceum* Roxb. (8) *P. miliaceum* L., *P. miliare* Lamk., Ragi (*Eleusine coracana* Gaertn.), are small-grained cereals commonly known as 'millets'. (9) *Andropogon sorghum* Brot. = *Sorghum vulgare* Pers. (10) Rye (*Secale cereale* L.) from which rye-bread is produced. (11) Bamboo (*Bambusa arundinacea* Willd.). (12) Sugarcane (*Saccharum officinarum* L.). (13) *Saccharum munja* Roxb., used in making crude writing pens for village school children. (14) *Saccharum spontaneum* L., used in inferior thatching and sand binding. (15) *Imperata arundinacea* Cyrill., used in superior thatching. (16) *Phragmites karka* Trin., the split stems of

which are woven into mats. (17) *Cynodon dactylon* Pers., a favourite pasture grass. (18) *Eleusine aegyptiaca* Desf. = *Dactyloctenium aegypticum* Beauv., a common grass used as fodder. (19) *Eleusine indica* Gaertn., a common weed. (20) *Eragrostis cynosuroides* Beauv. = *Desmostachya bipinnata* Stapf., used in religious ceremonies. (21) *Ischaemum angustifolium* Hack. = *Eulaliopsis binata* C. E. Hubb used in manufacturing paper. (22) *Andropogon squarrosus* Hack. = *Vetiveria*

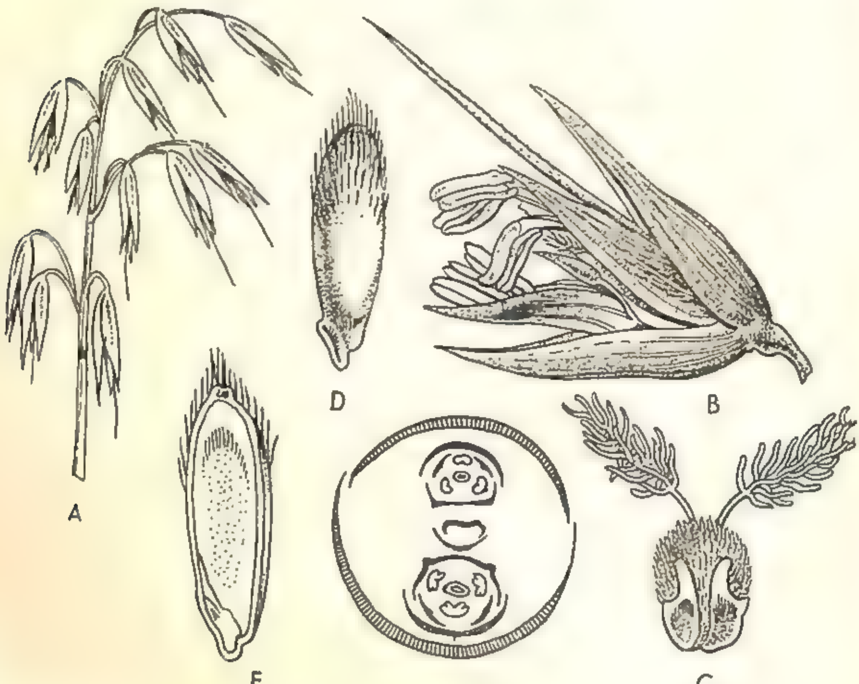


Fig. 491. Gramineae (*Avena sativa*).
A, Portion of a branch with spikelets; B, A spikelet; C, Pistil with lodicules; D, Grain; E, L.s. of the same; F, Floral diagram of a spikelet.

zizanoides Nash., the roots of which are woven into screens and hung against doors and windows after being wet. (23) Love grass (*Andropogon aciculatus* Retz. = *Chrysopogon aciculatus* Trin.), a pest of waste fields during the rains. (24) Jobs' tear (*Coix lachryma-jobi* L.). (25) *Panicum flavescens* Sw. = *Setaria barbata* Kunth., *Setaria glauca* Beauv., *Oplismenus compositus* Beauv., and *Leptochloa filiformis* Koem. = *L. panicea* Ohw. are characterized by the hygroscopic movements of their awn. (26) Seashore grass (*Spinifex squarrosus* L. = *S. littoreus*

Merr.), a sandbinding plant commonly found on the sand-dunes covering the Indian ocean. (27) *Digitaria sanguinalis* Scop. and *D. tenuiflora* Beauv., occur everywhere. (28) *Hygroryza aristata* Nees., commonly found floating on ponds and jhils. (29) *Thysanolaena agrostis* Nees. = *T. maxima* O. Ktze., a tall handsome grass.

Affinity

Though forming a very distinct family by itself, Gramineae resembles Cyperaceae in habit, but is readily distinguished by the characters of the flowers, fruits and seeds and the method of germination. It also differs in having a 2-ranked arrangement, fistular stem, an open sheath and in the presence of ligule. As in the sedges, the flowers are associated with scale-like glumes, but the arrangement of the floral members conforms to the typical trimerous type. A definite perianth cannot be recognized while the fruit with its one or two carpels is less specialized than those of sedges. The form and position of the embryo are also different. Moreover, the process of germination agrees to some extent with those of Palmae and Liliaceae.

Economic importance

This family stands first among angiosperms in economic importance. *Oryza sativa* and *Triticum sativum* supply the staple food-grains for the people of the whole world and are being cultivated from very ancient time. Millet is obtained from *Pennisetum typhoideum*, *Panicum miliaceum*, *P. miliare*, *Eleusine coracana*, etc. Barley is obtained from *Hordeum vulgare*. *Eleusine aegyptica* and *Panicum sativum* are used as fodder grass. *Secale cereale* is a medicinal plant. Several cultivated species are used for making fermented liquors. Sugar is obtained from the stem of Sugarcane. Bamboo is used all over India for erecting huts. Few grasses yield essential oils e.g., Ginger grass (*Andropogon odoratus* Dna.), Citronella grass (*Cymbopogon nardus* L.), Lemon grass (*C. citratus* Stapf.) and Geranium oil grass (*C. schoenonthus* Spreng). Some are used for thatching and paper-manufacturing.

CYPERACEAE

General characters

Plants—annual or more often perennial grass-like herbs, persisting in damp situations with a sympodial rhizome. Stem—

triangular and *solid throughout*. Leaves—*3-ranked* with a narrow blade, *leaf-sheath closed* eligulate. Flowers—*very minute*, subtended by chaffy bracts. Inflorescence—spikelets, arranged in spike, raceme, panicle or umbel and frequently subtended by foliaceous bracts. Perianth—represented by bristles or scales or absent. Stamens—usually in one whorl of 3, rarely only 1, with *basifixed* anthers. Carpels—3 or 2, united; ovary 1-celled with a solitary basal, erect,

Fig. 492. Cyperaceae (*Cyperus rotundus*).
A, An entire plant; B, An inflorescence; C, Flower; D, Stamen; E, Pistil; F, T.s. of ovary; G, Floral diagram.

anatropous ovule; style 1, with tripartite stigma. Fruit—*achene, utricle or nut*. Embryo—smaller than those of Gramineae and lies at the base of the seed in the central line surrounded by endosperm; the cotyledon comes out of the sheath at the time of germination.

Number and distribution

This family consists of about 72 genera and 3,200 species distributed everywhere as marsh plants.

Key to Genera

A. Ovary and fruit enclosed in a utricle .. .. *Carex*.

B. Ovary and fruit not enclosed in a utricle—

(*a*) Flowering glumes distichous, scales or bristles *O*

(*i*) Style 2-fid; rachilla of spikelets deciduous: perennial herbs; stem trigonous; leaves narrow, radical .. *Kyllinga*.

(*ii*) Style 3-fid; rachilla of spikelets persistent; fruit trigonous; perennial or annual herbs; leaves all towards the base of stem or sometimes a few cauline, occasionally reduced to sheaths .. .. *Cyperus*.

(*b*) Flowering glumes spirally arranged; base of style passing gradually into the fruit, and constricted or articulated; glabrous herbs, often tall, leafless or leafy at the base only; stem terete, trigonous or triquetrous *Scirpus*.

Range of floral structures

The flowers are usually bisexu. l, but naked unisexual flowers occur in *Carex*. In this genus the male flower forms a simple spike, each of which being subtended by a bract, whereas the female flowers form a compound spike. The bract subtending the flower is represented by utricle. In *Uncinia*, the secondary axis becomes elongated and forms a bristle-like projection. The secondary axis in *Elyna* bears a male flower above the female one.

The perianth is represented by hairs (e.g., *Eriophorum*), or bristles (e.g., *Scirpus*), or scales. In *Oreobolus*, the perianth is glumaceous which consists of 6 members arranged in two whorls of 3 each. The members of the perianth may be reduced by abortion of one member or they may become numerous, as in *Rhynochospora* and *Eriophorum*.

Androecium consists of 6 stamens, usually arranged in two whorls of 3 each or only 3 stamens sometimes occur, the inner whorl being entirely absent. In *Hemicarpha*, and *Bisboeckelera*, the number of stamen is only one.

Gynoecium consists of either 3 or 2 carpels, which are united. Both forms of carpel occur in the species of *Carex*. The number of stigma corresponds to the number of carpels. The style often becomes thickened at its base and forms a beak-like structure which crowns the fruit. The ovary is superior, 1-celled with a single basal ovule.

Common plants

(1) Common Sedge (*Cyperus rotundus* L.), a weed of cultivated lands. (2) Mat-grass (*Cyperus tegetum* Roxb.), the split stems of

which are woven into ordinary mats. (3) *Scirpus grossus* L.f., the black tubers of which are edible. (4) Club-rush (*Scirpus littoralis* Schrad.), commonly found in the Sundribans. (5) *Fimbristylis junciformis* Kunth., commonly found on wet lands. (6) *Fimbristylis complanata* Link., a common weed with glabrous stem flattened under the umbel. (7) *Juncellus inundatus* Clarke, the split stems of which are also woven into mats. (8) *Kyllinga brevifolia* Rottb., a common weed with white globose heads. (9) *Remirea maritima*, a common sand-binding plant. (10) Slough grass (*Carex indica* L.), also commonly found on sandy places and very efficient in binding sand.

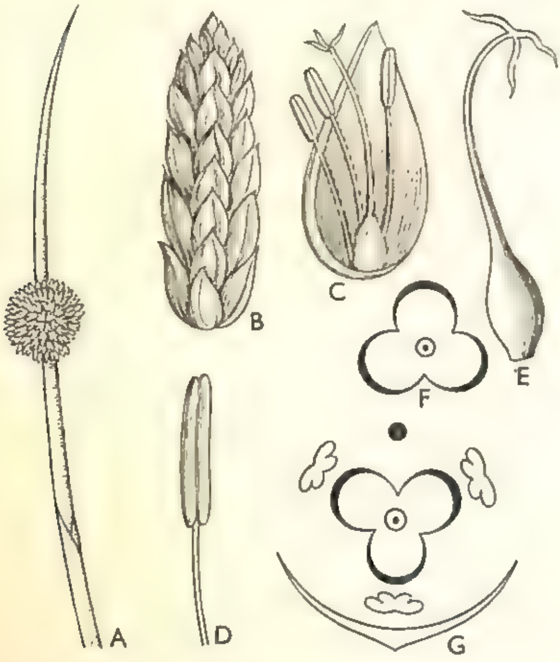


Fig 493. Cyperaceae (*Scirpus articulatus*). A, Portion of a flowering shoot; B, Inflorescence; C, Flower; D, Stamen; E, Pistil; F, T.s. of ovary; G, Floral diagram.

Affinity

The Cyperaceae have been found to be basically similar to Gramineae, particularly from the standpoint of origin. Hutchinson has regarded Gramineae (Graminales) to be the more highly advanced than Cyperaceae and opined that both the families have been derived from spikaceous ancestors through Juncaceae complex. Snell and Blaser were of opinion that Gramineae could not be taken as close allies to Cyperaceae. Blaser (1940) indicated that the spikeletes of Cyperaceae could not be homologous with those of the grasses, as the former family varies widely regarding organization but in the latter the organization remains almost constant. Holthem (1948) has indicated that the genus *Carex* is the most highly

evolved when treated from the point of floral construction in the family, and hence he has placed it in a separate subfamily Caricoideae along with other two subfamilies such as Scirpoideae and Rhynchosperaceae.

Economic importance

This family is economically important. The roots of *Kyllinga* are aromatic. The bristles of perianth of the genus *Eriophorum* are used in stuffing pillows, cushions, etc. *Cyperus tegetum* and *Juncellus inundatus* are used for manufacturing mats. *Scirpus grossus* yields edible tubers. *Cyperus rotundus* is used in the kaviraji system of medicine as a specific for dysentery. *Remirea* and *Carex* are sand-binding plants.

Comparison between Gramineae and Cyperaceae

Gramineae	*Cyperaceae*
1. Stem—usually fistular, round.	1. solid, triangular.
2. Leaves—2-ranked, sheath split up, with ligule.	2. 3-ranked, sheath closed, without ligule.
3. Perianth—represented by 2 or 3 lodicules.	3. represented by bristles or scales or absent.
4. Stamens—usually 3, sometimes 6, with versatile anthers.	4. usually 3, rarely 1, with basifixed anthers.
5. Carpel—1.	5. (3) or (2).
6. Style—usually 2 with feathery stigmas.	6. always one, with 3-partite stigma.
7. Fruit—caryopsis.	7. achene, utricle or nut.

ORDER 5. PRINCIPES

Generally woody plants with a stout unbranched stem ending in a crown of leaves; flowers small trimerous, usually on compound spadices which are enclosed by one or more large spathaceous bracts in bud; carpels 3, free or variously united; fruit a fibrous drupe or berry; seed with copious endosperm and a minute embryo.

According to Engler and Prantl, this Order constitutes the 5th Order of monocotyledons which includes a single family Palmae. Bentham and Hooker have placed this family under the series Calycinae. Hutchinson has designated this family as Palmaceae and as well as McLean and Cook have followed the same designation. Lawrence has placed the family in the Order Principes after Glumifloreae and before Synanthae.

PALMAE

General characters

Plants—majority are trees with a stout, erect, unbranched cylindrical stem, having short internodes covered with leaf-scars

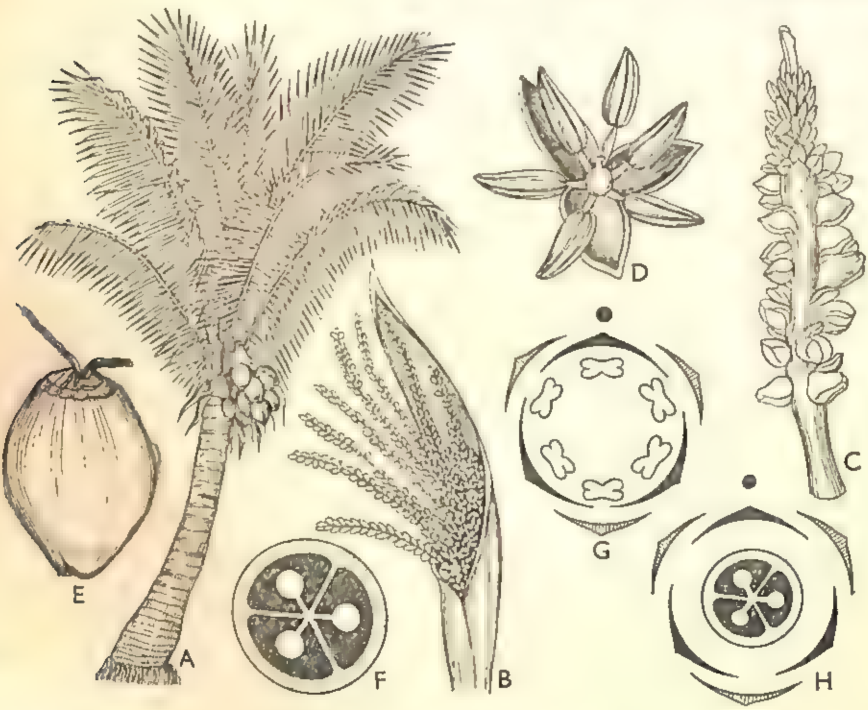


Fig. 494. Palmae (*Cocos nucifera*).
A, Plant; B, Inflorescence enclosed in a spathe; C, A rachilla with the spathe removed; D, Staminate flower; E, Fruit; F, T.s. of ovary; G, Floral diagram of staminate flower; H, The same of pistillate flower.

(or the bases of leaf-stalks), and ending at the top in crown of a few large foliage leaves closely packed together (excepting *Calamus*),

sometimes scrambling, occasionally acaulescent; the erect types may be sometimes branched, as in Doum palm (*Hyphaene theboica*) and several others. Leaves—simple, pinnate or palmate, often very large, with well-developed petiole and a broad persistent sheathing base, *plicate*. Inflorescence—usually lateral, *simple or compound spadix* or a richly branched panicle, often very large, bearing numerous small flowers enclosed either in one woody, boat-shaped spathe or several spathes, in the latter case, one for each branch. Flowers—sessile, *generally unisexual* (monoecious or dioecious), regular, arranged in a close spiral upon the axis of the inflorescence. Perianth—3+3, green, yellow or white, *persistent* and more or less leathery or fleshy. Stamens—usually 6, in 2 whorls, rarely 3 (e.g., *Nipa*). Carpels—3, either free or united; *ovary superior, 3-celled* with 1 anatropous or orthotropous ovule in each cell, but often during ripening 2 carpels with their ovules become abortive (e.g., Coconut); style short. Fruit—berry or fibrous drupe. Seeds—albuminous. Embryo—minute, embedded in a copious endosperm.

Number and distribution

This family consists of 210 genera and about 4,000 species which are chiefly confined to the tropical regions.

KEY TO GENERA

A. Leaves flabelliform, fan-shaped or orbicular:
- (*a*) Monocarpic palms, flowering once and then dying; flowers bisexual .. .. *Corypha.*
- (*b*) Polycarpic palms, flowering year after year—
  - (*i*) Flowers bisexual—
    - Ovary of 3 triangular carpels .. .. *Licuala.*
    - Ovary of 3 globose carpels .. .. *Livistona.*
  - (*ii*) Flowers unisexual; male flowers small, female flowers very large .. .. .. *Borassus.*

B. Leaves pinnate:
- (*a*) Fruit not covered with scales—
  - (*i*) Leaves twice pinnatisect .. .. .. *Caryota.*
  - (*ii*) Leaves completely or partially once pinnatisect—
    - Dwarf palms of tidal swamps, branching (buried) *Nipa.*
    - Tall palms with erect unbranched stems; fruit large ovoid nut with a fibrous husk .. .. *Cocos.*

Tall or short palms with pinnatisect leaves, segments lanceolate or ensiform with margin induplicate; flowers dioecious, small, yellowish; fruit yellow or bright red to blue black .. .. *Phoenix.*

Slender palms with erect annulate stems; leaves pinnatisect, distal segments confluent; flowers monoecious on branched intrafoliar spadices, male flowers minute, female much larger; perianth accrescent .. .. .. *Areca.*

(*b*) Fruits covered with imbricating scales; stems climbing, rarely erect, armed .. .. .. *Calamus.*

Range of floral structures

The flowers are generally unisexual, but bisexual flowers also occur sometimes, as in *Livistona*, *Licuala*, *Trachycarpus*, etc. The male and female flowers occur either on the same plant (e.g., *Cocos*) or on different plants (e.g., *Phoenix*). The arrangement and the position of the male and female flowers vary in different genera. In *Raphia ruffia*, the female and the male flowers are arranged in the lower and the upper halves respectively. In *Geonoma*, the male and female flowers become intermingled. In such case, a central female flower with one male on both sides is enclosed by a bract of the so-called fleshy spike. There occurs considerable variation in the size of the flowers, as in *Borassus*, where the female ones are larger than the minute male ones.

The number of the perianth is 6, arranged in two whorls of 3 each. They are generally polyphyllous, but sometimes united. In *Areca catechu*, the inner whorl of perianth leaves become very much larger than the outer whorl.

Variation in the number of stamens takes place. Usually there are 6 stamens arranged in 2 whorls of 3 each. But 3 stamens are found in *Nipa*, which is due to the suppression of the stamens of the inner whorl. The stamens sometimes are of indefinite number, as in *Pinanga*, *Caryota*, etc.

Variation in the number of carpels and position of the ovules are noted occasionally. Usually the pistil is tricarpellary but monocarpellary one occurs in *Cocos nucifera*, where out of 3 carpels two abort during the process of ripening of the fruit.

The ovary is generally 3-celled, but it is 1-celled in *Areca catechu*. The form of ovules varies from anatropous (e.g., *Geonoma*, *Areca*) to orthotropous which is very rarely found.

Common plants

(1) Palmyra palm (*Borassus flabellifer* L.). (2) Coconut palm (*Cocos nucifera* L.). (3) Date palm (*Phoenix sylvestris* Roxb. and *P. dactylifera* L.). (4) Betelnut palm (*Areca catechu* L.). (5) Cane-palm (*Calamus tenuis* Roxb.); Rattan cane (*C. rotang* L.). (6) Water coconut (*Nipa fructicans* Wurmb.), chiefly found in the Sundribans. (7) *Phoenix paludosa* Roxb., also found in the Sundribans. (8) Sago palm (*Metroxylon rumphii* Mart. = *M. sagus* Roltb.). (9) Fish-tail palm (*Caryota urens* L.), commonly planted in gardens. (10) Royal palm (*Oreodoxa regia* = *Roystonia regia* O. F. Cook.) is one of the finest specimens of the family and can be seen planted on both sides of the Oreodoxa Avenue in the Indian Botanic Garden. (11) Talipot palms (*Corypha elata* Roxb. and *C. umbracaulifera* L.), are very common in gardens. (12) *Licuala peltata* Roxb., a gregarious shrub. (13) *Livistona chinensis* R. Br., a tree, 20-30 ft. high, frequently cultivated.

Affinity

Bentham and Hooker placed this family under the series Calycinae for its sepaloid calycine perianth. On the basis of homochlamydeous, trimerous, unisexual flowers the family has been placed under Princeps by Engler. The presence of universal spadix and unisexual flowers led Rendle to put Palmae with Araceae under Spadiciflorae. Hutchinson is of opinion that the palms have been derived from liliflorean stock and he placed the group under separate Order Palmales. According to Wettstein, Palmae seem to be closely related to Pandanaceae and Cyclanthaceae. This family is also allied to Araceae but readily distinguished by the habit, character of ovary, fruit and seeds. The two-whorled trimerous perianth, 6 stamens and tricarpellary superior ovary bring it in close relation to Liliaceae.

Economic importance

This family is of great economic importance as it includes a large number of economic plants. *Cocos nucifera* is one of the most important economic plants, which yields coconut oil of commerce. In addition to this product, it also produces various other substances which are utilized for different purposes. The fibrous mesocarp is utilized in the production of ropes, mats, brushes, etc. The sugary sap derived by tapping the young inflorescence is used for alcoholic

drink, and toddy yields vinegar. *Phoenix dactylifera* produces common edible dates; the wood of this plant is used in making water-pipes; the leaves are used for thatching purposes, mats, baskets, fans, etc. *P. sylvestris* is a common sugar-yielding plant. The common fan-palm (*Borassus flabellifer*), produces molasses and sugar from its juice secreted by tapping the inflorescence; it also yields strongest timber in making the posts, pillars, etc. *Elaeis guineensis* Jacq., yields a valuable oil. *Copernicia*, the common Cannuba palm, is a wax-yielding plant and it is used for making gramophone records, candles, etc. *Corypha umbracaulifera* (Talipot

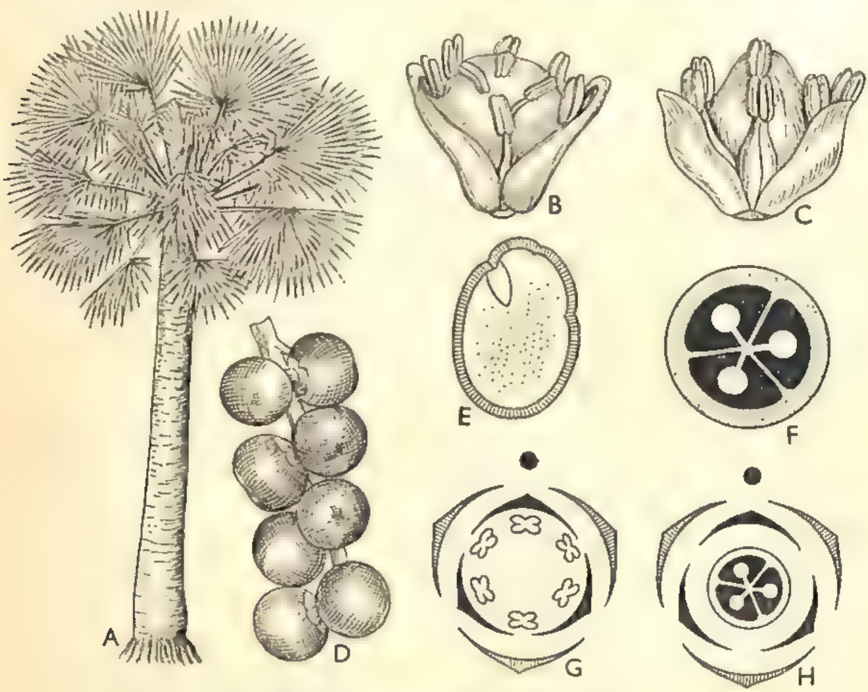


Fig. 495. Palmae (*Borassus flabellifer*).
A, The plant; B, Staminate flower; C, Pistillate flower; D, Fruits;
E, L.s. of seed; F, T.s. of ovary; G, Floral diagram of staminate flower;
H, The same of pistillate flower.

palm) produces umbrella from the leaves; the split leaves are utilized in making mats, baskets, fans, etc. *Calamus rotang* yields valuable canes. *Areca catechu* is the common betel-nut palm, the seeds of which are cut into slices and taken with the leaves of betel; a sort of powder is derived from the roasted seeds; the leaves are used for thatching purpose. *Phytelephas*, the common vegetable ivory, is

largely used by American people; the hard endosperm of the seed is generally edible. *Metroxylon rumphii* produces common sago which is derived from the pith by crushing and washing. *Caryota urens* produces a sort of toddy rich in vitamins, which is used in tuberculosis. Many species are cultivated in gardens as ornamentals.

ORDER 7. SPATHIFLORAE

Generally herbs or climbers; leaves large; flowers small, unisexual or bisexual, crowded on a fleshy spadix which is subtended by a single large bract or spathe; perianth absent or much reduced but never petaloid; ovary superior; fruit berry; seed with copious endosperm and a minute embryo.

According to Engler, this Order comprises of two families, viz., Araceae* and Lemnaceae*. Bentham and Hooker have placed these families under the series Nudiflorae. Hutchinson, however, places these families under the Order Arales.

ARACEAE

General characters

Plants—usually terrestrial herbs (but aquatic in *Pistia*), often large or even tree-like, rarely shrubs sometimes climbing, generally with acrid watery latex; resin passages and mucilage sacs sometimes occur. Leaves—radical or alternate (in climbing species), generally net-veined, sometimes long and narrow with parallel veins (e.g., *Acorus calamus*). Inflorescence—*spadix with a spathe* which may be green (e.g., Arum), petaloid (e.g., *Richardia*), or brilliant scarlet (e.g., *Anthurium*). Flowers—small, inconspicuous with dimerous or trimerous whorls, bisexual or unisexual, closely crowded on the spadix without bracteoles. Perianth—absent (in unisexual flowers) but present in bisexual flowers, of 4-6 scales which may be free or united. Stamens—2, 4 or 8, with the filaments more or less united at the base (e.g., *Arisaema*), or throughout their length (e.g., *Colocasia*, *Alocasia*), or to a single stamen (e.g., *Arisarum*); in *Pistia* the male flower is reduced to two anthers which are united; staminodes sometimes present in the female flowers. Carpels—(3), usually reduced to one (e.g., Arum, *Pistia*); ovary superior, sometimes inferior, 1-many-celled, ovules few to numerous in each cell on basal, parietal or axile placentae;

stigma 1 or more. Fruit—berry. Seed—albuminous, embedded in a mucilagenous pulp, or exalbuminous. Embryo—*minute* and *straight*.

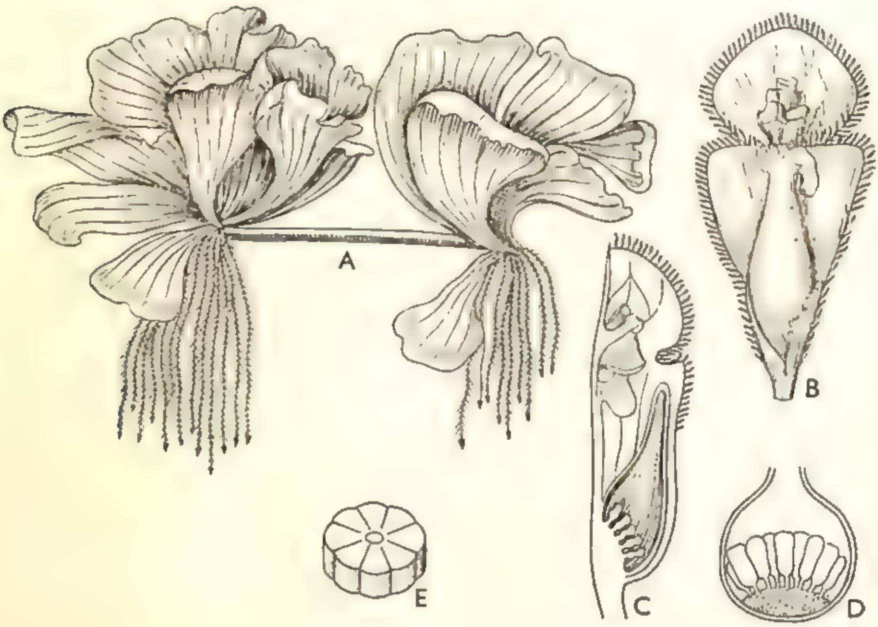


Fig. 496. Araceae (*Pistia stratiotes*).
A, Plant; B, Inflorescence enclosed in the spathe; C, V.s. of the same; D, L.s. of ovary; E, Fruit.

Number and distribution

This family consists of about 105 genera and 1,400-1,500 species which are generally found in the temperate and tropical regions but especially developed in the warmer regions of the globe.

KEY TO GENERA

A. Flowers unisexual, monoecious, rarely dioecious:

(*a*) Aquatic plants—

Floating stemless herbs; leaves sessile in a rosette-like tuft .. .. *Pistia*.

Submerged aquatic or marsh herbs; leaves tufted from a buried rootstock .. .. .. *Cryptocoryne*.

(*b*) Terrestrial herbs—

Tuberous; leaves entire, 3-5-lobed, cordate or hastate or pedate; flowers and leaves present together .. *Typhonium*.

Tuberous; leaves solitary, 3-partite, segments pinnatisect; flowers appearing without leaves, male and female flowers contiguous, neuter wanting .. *Amorphophallus*

Herbs, usually tall, coarse; leaves and scapes arising from the rhizome; leaves may be peltate; spadix with a barren appendage, not adnate to the spathe—

Ovules few, basal .. .. .. *Alocasia.*

Ovules many, parietal .. .. .. *Colocasia*

B. Flowers bisexual:

(*a*) Epiphytic climbing herbs—

Perianth absent, berries free, ovule solitary .. *Scindapsus.*

Perianth of 4-6 segments, ovule solitary, plant unarmed .. .. *Pothos.*

(*b*) Stout spinous aquatic or marsh herbs .. .. *Lasia.*

Range of floral structures

This family shows great variations in floral structures. The flowers are bisexual with typical trimerous arrangement $P_{3+3}A_{3+3}G_{(\underline{3})}$ (e.g., *Acorus*), or with dimerous whorls (e.g., *Anthurium*), or dimerous arrangement with reduction to one in gynoecium (e.g., *Gymnostachys*). The flowers are bisexual and naked, as in *Calla*, or unisexual and naked with male flowers on the upper and female on the lower portions of the spadix, as in Arum, *Alocasia* and others.

The spathe is green, as in Arum, or petaloid, as in *Richardia*, or it assumes brilliant scarlet colour, as in *Anthurium.*

Perianth is either present or absent. The perianth leaves are united (e.g., *Spathiphyllum*), or free (e.g., *Acorus*). They are generally absent in unisexual flowers but are present in bisexual flowers.

Androecium forms two whorls or a single whorl and in the latter case, the filaments are connate to some extent at the base (e.g., *Dracunculus*, *Arisaema*), or filaments are united throughout their length and form a synandrium, as in *Colocasia*, *Alocasia*. The male flowers are found to be reduced to form synandrium by two anthers, (e.g., *Pistia*). In *Arisarum* and *Biarum*, there is a single stamen.

Carpels are generally three, but one carpel is present in Arum and *Pistia*. Ovary is superior or sessile. The ovary becomes 1-many chambered with few to indefinite ovules. The placentation may be of various types, such as, parietal, axile or marginal.

Common plants

(1) Common Arum or Taro (*Colocasia antiquorum* Schott. -*C. esculenta* Schott.), a herb chiefly cultivated for its edible rhizome. (2) *Alocasia indica* Schott., also cultivated for its rootstock. (3) *Scindapsus officinalis* Schott., a root-climber of gardens. (4) *Sauromatum* Schott., also a common garden climber with golden-yellow leaves. (5) *Typhonium trilobaium* Schott., commonly found in waste places. (6) Teliga potato (*Amorphophallus campanulatus* Bl.), commonly cultivated for the edible corm, also found wild. (7) Water lettuce (*Pistia stratiotes* L.), a common floating herb with rosettes of radical leaves. (8) *Cryptocoryne ciliata* Fisch., an aquatic herb on the muddy banks of

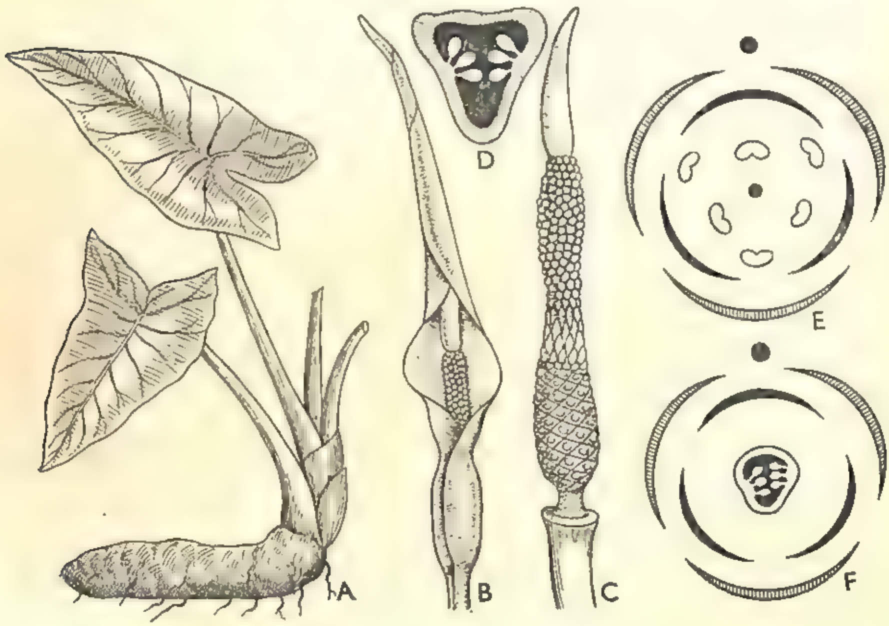


Fig. 497. Araceae (*Colocasia antiquorum*).
A, The plant; B, Inflorescence enclosed in a spathe; C, The same with the spathe removed; D, T.s. of ovary; D, Floral diagram of staminate flower; E, The same of pistillate flower.

the Ganges, characterized by the viviparous mode of germination of the seeds. (9) *Pothos scandens* L., a gigantic root-climber, common in gardens. (10) Arum lily (*Richardia ethiopica* Kunth.), a herb with thick rootstock and large white trumpet-like spathe; very common in Darjeeling. (11) *Arisaema speciosum* Mart., grows in Darjeeling

and has a long tail and a spotted hood-like spathe which looks like a fearful snake from a distance, an instance of mimicry. (12) *Lasia heterophylla* Schott., occurs in swampy places.

Affinity

Hutchinson is of opinion that Araceae has been developed as a separate phylum from Liliflorae. Lotsy assumes that Palms, Aroids and Pandanales have been derived from the Piperales. Such contrast with Piperaceae is mainly based on the floral structure and inflorescence of the latter which simulate with such trend of Araceae. The plants of this family, though strikingly different in general habit, are closely allied to Palmae in such important characters, as the relative size of the embryo and endosperm, while in both we notice the large development of the spathe and the association of a large number of small, inconspicuous flowers in often huge, indefinite inflorescences. Araceae, on the other hand, is closely allied to Lemnaceae which is evidently a much reduced member of Aroid type, the reduction proceeding so far as to affect the vegetative and reproductive organs.

Economic importance

This family consists of several economic plants. An aromatic essential oil is obtained from Sweet flag (*Acorus calamus*). The underground stems of *Colocasia*, *Alocasia* and *Amorphophallus* are eaten as vegetables. A kind of fibre is derived from the stem of *Scindapsus*. The fruits of *Monstera* are often taken for delicate flavour. Some plants are cultivated as ornamentals, such as, *Philodendron*, *Anthurium*, *Caladium*, *Pothos*, *Scindapsus*, etc.

LEMNACEAE

General characters

Plants—small, floating, perennial herbs with a *thalloid leaf-like shoot*, monoecious. Flowers—unisexual, naked or enclosed by a membraneous sheathing spathe. Stamens—in male flower *one;* anther 1-2-celled; filament absent or if present filiform or fusiform. Carpel—in female flower *one;* ovary superior, flask-shaped, 1-celled with 1-7, basal, erect ovules; stigma short, *funnel-shaped*. Fruit—*utricle*. Seed—with or without endosperm.

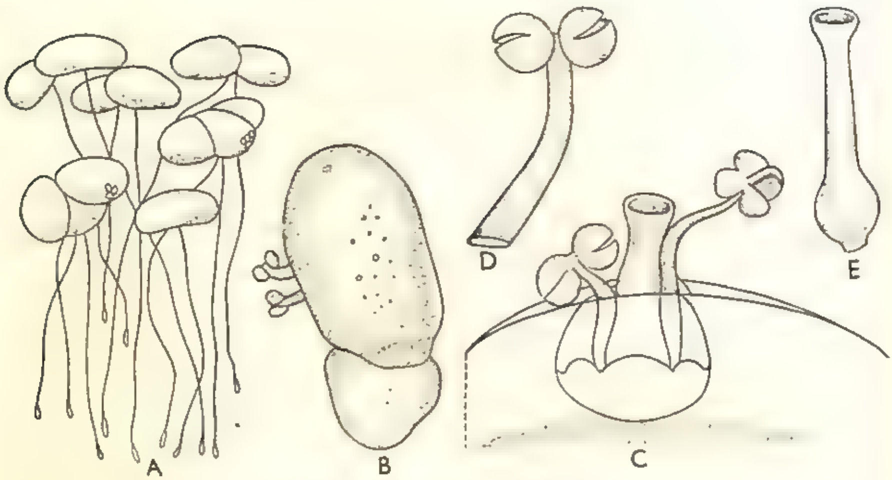


Fig. 498. Lemnaceae (*Lemna minor*).
A, A group of plants; B. Portion of a flowering shoot; C, A three-flowered inflorescence enclosed in a sheath; D, Staminate flower; E, Pistillate flower.

Number and distribution

This family consists of 3 genera with 25 species, which are distributed throughout the world except the Arctic region.

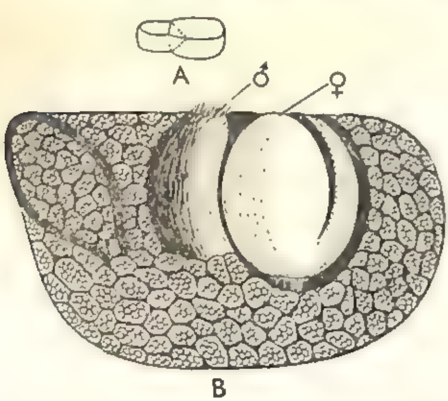


Fig. 499. Lemnaceae (*Wolffia arrhiza*).
A, Plant; B, V.s. of the same (highly magnified).

Common Plants

(1) Duck weed (*Lemna trisulca* and *L. minor*) are common floating herbs, measuring about 1/8th to 3/4ths of an inch, covering the surface of tanks and pools as a compact green mass. (2) *Wolffia arrhiza*, smallest flowering plant measuring about 1/20th of an inch. (3) *Spirodela polyrrhiza*, another common floating herb.

Affinity

This family is readily distinguished from Araceae by much reduced dorsiventrally thalloid shoot, the number of stamens and carpels, funnel-shaped stigma and nature of fruit.

ORDER 8. FARINOSAE

Generally herbaceous, sometimes grass-like in habit; flowers bisexual or unisexual, cyclic, trimerous, sometimes dimerous, often with reduction in the androecium: ovary superior, compound: ovule orthotropous; seed with copious *mealy endosperm* (hence the name of the Order).

According to Engler and Prantl, this is the 8th Order of monocotyledons containing 13 families. Commelinaceae and Pontederiaceae are two such of them. Bentham and Hooker have placed Commelinaceae under the series Coronarie. Rendle following Engler has put the family in Farinosae. Hutchinson has made a separate rank of the Order Commelinales.

COMMELINACEAE

General characters

Plants—annual or perennial herbs with swollen nodes. Leaves—alternate, simple, with prominent sheath. Inflorescence—monochasial (helicoid) cymes arising from the axil of a foliage leaf or of a spathe-like bract; bracteoles sometimes present. Flowers—*irregular*, sometimes zygomorphic, bisexual, hypogynous. Perianth—3+3, distinguished into calyx and corolla; sepals generally free, petals commonly *blue*, generally free. Stamens—6, all perfect or only 3, outer being staminodes (but staminodes absent in *Collisea*); filaments often hairy. Carpels—(3); ovary superior, 3-celled, rarely 2-celled by suppression, with solitary or few orthotropous ovules in each cell; style terminal; stigma generally capitate. Fruit—*capsule*. Seed—*angled*, albuminous (mealy endosperm). Embryo—at the apex of the opposite end of the hilum.

Number and distribution

This family consists of 37 genera and about 600 species distributed throughout the tropics but absent from Europe and temperate Asia.

KEY TO GENERA

A. Stamens 3 perfect, and 1-3 staminodes:

(*a*) Cymes solitary, enclosed in spathaceous bract; one petal larger than others and often clawed . .. *Commelina*.

(b) Cymes paniculate, not enclosed in spathes; petals all equal .. .. *Aneilema.*

B. Stamens 6 perfect:

Petals united below in a tube .. ... *Cyanotis.*

Common plants

(1) *Commelina benghalensis* L., a very common weed of ditches and other moist places with ordinary subaerial flowers and cleistogamous flowers buried under the ground. (2) *Commelina appendiculata* Clarke and *C. obliqua* Ham., are common weeds of ditches. (3) Spider-wort (*Tradescantia virginiana* L.) and *T. bicolor* = *Rheo discolor* Hance, common garden herbs, the staminal hairs of which exhibit circulatory motion of the protoplasm. (4) *Cyanotis axillaris* Roem. & Schult., a common weed found in cultivated lands. (5) *Aneilema spiratum* R. Br. = *Murdania spirata* Bruckner, *A. vaginatum* R. Br.

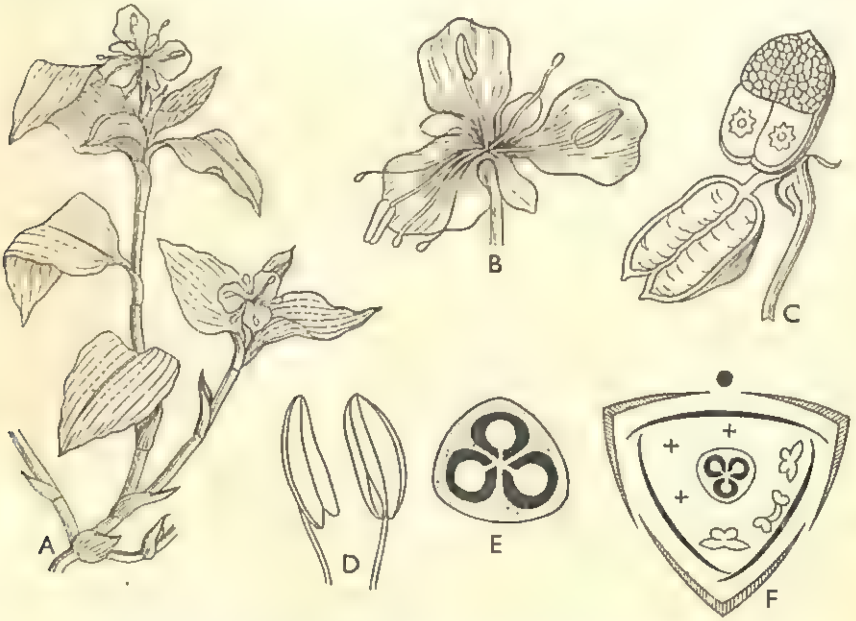


Fig. 500. Commelinaceae (*Commelina benghalensis*).
A, Portion of a flowering shoot; B, Flower; C, Dehiscence of fruit; D, Stamens; E, T.s. of ovary; F, Floral diagram.

= *Murdania vaginatum* Bruckner and *A. nudiflorum* R. Br. are common weeds of fields and in wet places.

Affinity

The affinity of this family is still problematic. According to Hutchinson Commelinaceae establishes a close link between Helobiae and Liliflorae. He has also asserted that Commelinaceae is phylogenetically related to different taxa of the families of the Order Farinosae, regarding the characters of mealy endosperm and the perianth differentiation into calyx and corolla. The Commelianaceae may be closely related to Pontederiaceae on the basis of mealy endosperm, ligular ochrea-like sheath and in the resemblance of floral structure of *Pontederia* (Pontederiaceae) and *Spironema* (Commelianaceae).

Economic importance

This family is of little economic importance. *Rheo discolor* is a favourite garden plant. Other ornamental plants are *Cyanotis*, *Aneilema*, *Floscopa*, etc. The leaves of *Commelina benghalensis* are edible.

PONTEDERIACEAE

General characters

Plants —*aquatic perennial herbs*, erect or floating or rooting in the substratatum. Stem—main stem slender or stout, buried or unraised rootstock with fibrous roots. Leaves—arising singly on the stem, mostly enveloped with sheathing leaf-base, *fleshy, with long swollen petiole*. Inflorescence—terminal raceme or spike, rarely panicle, with spathaceous bracts. Flowers—slightly irregular, *medianly zygomorphic*, bisexual, hypogynous, with minute or obsolete bracts and bracteoles. Perianth—3+3, petaloid, usually tubular, persistent, imbricate. Stamens—usually 3+3, rarely uniseriate with outer row of 3 stamens absent, adnate to the perianth lobes; anthers elongated, basifixed or dorsifixed, with longitudinal or porous dehiscence; filaments filiform. Carpels—(3); ovary superior, *3-celled* with axile placentation or *1-celled* with parietal placentation with many ovules, arranged in two series. Fruit—a loculicidal 3-valved capsule or 1-seeded achene. Seeds—with cylindrical embryo and *mealy endosperm*.

Number and distribution

This family consists of 7 genera and about 28 species. All are aquatic or marsh plants distributed in the warm parts of the globe.

KEY TO GENERA

A. Ovary trilocular

Stamens 6 in two series .. .. .. *Eichhornia.*

Stamens 3 in one series .. .. .. *Heteranthera.*

B. Ovary unilocular .. .. *Pontederia.*

Fig. 501. Pontederiaceae (*Eichhornia crassipes*).
A, An entire plant; B, L.s. of a flower.

Common plants

(1) *Eichhornia crassipes* Solms. (Water hycanth), widely distributed in stagnant or slow moving fresh water, (2) *Pontederia sagittata* L., *P. vaginalis* L. and *P. plantaginea* L. are aquatic herbs, distributed in all provinces.

Affinity

According to Hutchinson and Schwartez presence of six petaloid perianth lobes suggests an affinity with Liliaceae but is separated from the latter family by the presence of zygomorphic flowers and seeds with mealy endosperm.

Economic importance

Eichhornia and *Pontederia* are usually cultivated in pools and lakes as aquatic ornamentals.

ORDER 9. LILIFLORAE

Generally perennial herbs: flowers bisexual; regular or sometimes irregular, typically 3-merous: perianth petaloid but glumaceous (Juncaceae); stamens 3-6; carpels (3); ovary superior or inferior, 3-celled; ovules generally anatropous; fruit capsule or berry; seeds with copious fleshy or bony endosperm.

According to Engler, this Order comprises 9 families, viz. Juncaceae, Stemonaceae, Liliaceae*, Haemodoraceae, Amaryllidaceae*, Velloziaceae, Taccaceae, Dioscoreaceae, Iridaceae, etc. Bentham and Hooker have placed Liliaceae under the series Coronarieae, and Amaryllidaceae under the series Epigynae. Hutchinson places Liliaceae under the Order Liliales and Amaryllidaceae under Amaryllidales.

LILIACEAE

General characters

Plants—mostly perennial herbs with bulbous or rhizomatous stems, sometimes climbing (e.g., *Smilax*, *Gloriosa*) or arborescent (e.g., *Dracaena*, *Yucca*, *Aloe*). Leaves—simple, radical or cauline (alternate or whorled, but opposite in *Scolyopus*), rarely compound (e.g., *Paris polyphylla*). Inflorescence—generally racemose, sometimes cymose. Flowers—regular, bisexual, rarely unisexual (e.g., *Smilax*), hypogynous. Perianth—3+3, free or united, petaloid, sometimes sepaloid. Stamens—3+3; anthers introrse or extrorse. Carpels—(3); *ovary superior*, 3-celled with many or few anatropous ovules in each cell; styles separate or united. Fruit—a septicidal or loculicidal capsule, sometimes berry. Seed—with a small embryo and copious fleshy or bony endosperm.

Number and distribution

This family consists of about 240 genera and 4,000 species of world-wide distribution.

KEY TO GENERA

A. Shrubs with perennial stems above ground; fruit berry-like—

(*a*) Stems without green leaves, usually straggling, leaves replaced by linear or acicular cladodes with minute scales .. .. *Asparagus.*

(*b*) Stems leafy—

(*i*) Leaves 3-5-nerved, reticulately veined; leaf-base with 2 tendrils .. .. .. *Smilax.*

(*ii*) Leaves parallel veined, numerous, usually clustered at the apex of an erect caudex; each cell of ovary 1-ovuled .. .. *Dracaena.*

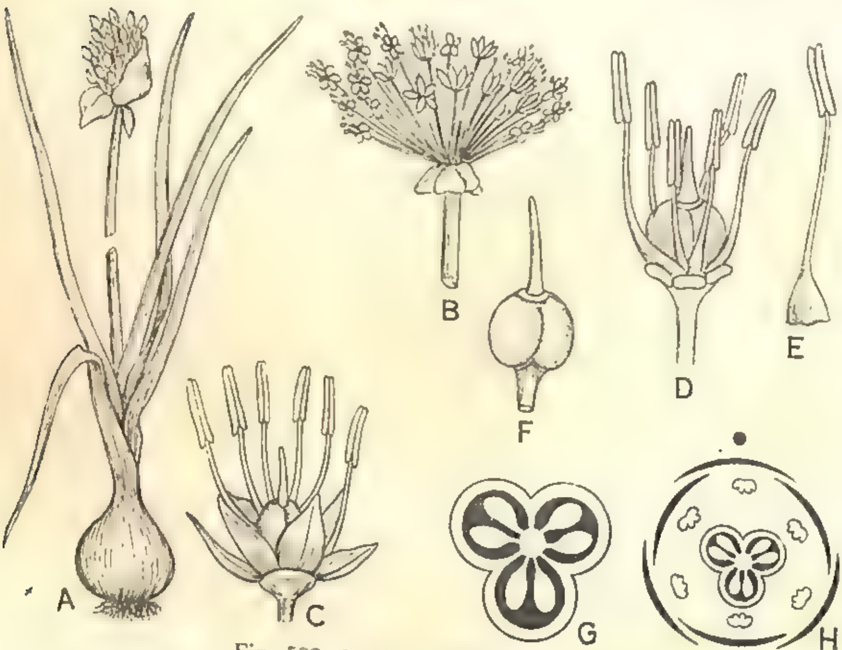


Fig. 502. Liliaceae (*Allium cepa*).
A, Plant; B, Inflorescence; C, Flower; D, The same after removal of perianth; E, Stamen; F, Pistil; G, T.s. of ovary; H, Floral diagram.

B. Climbing herbs with leafy stems; leaves with a long, tendril-like apex; flowers large, showy .. .. *Gloriosa.*

C. Herbs with tunicated bulbs and characteristic odour, strong or pungent; leaves radical, fistular or flat, enveloping the scape below; flowers umbellate or capitate at the top of the scape, at first enclosed in an involucre of bracts .. .. *Allium.*

Common plants

(1) Onion (*Allium cepa* L.) and (2) Garlic (*Allium sativum* L.) are chiefly cultivated for their edible bulbs. (3) *Asparagus racemosus* Willd., a common prickly climber with fasciculated roots and cladodes. (4) Glory lily (*Gloriosa superba* L.), a climber commonly found in dry places with apices of leaves converted into tendrils. (5) Sarsaparilla (*Smilax macrophylla* Roxb. = *S. zeylanica* L.), a prickly climber with reticulate venation and stipular tendrils. (6) *Aloe perfoliata* Willd. and *A. vera* L., common herbs with dentate fleshy leaves. (7) *Dracaena terniflora* Jack. and *Yucca gloriosa* L. are common tree-like shrubs, often cultivated in gardens. (8) *Hemerocallis fulva* L. and *Asphodelus tenuifolius* Cav., are common garden plants. (9) *Colchicum luteum* Baker., a medicinal plant chiefly found in the hills.

Affinity

Liliaceae resembles very much Amaryllidaceae except in the character of superior ovary. Juncaceae also bears a close affinity to Liliaceae. It is considered to be polyphyletic in origin from the standpoint of cytological variabilities, embryological and anatomical structures. Liliaceae is also supposed to have been derived from Helobieae or its ancestor based on the floral structures of a few genera belonging to Liliaceae, such as, *Petrosavia*, *Protolirion*, etc., which possess semi-free carpels.

Economic importance

This family is of some economic importance. Tulips, Lilies, Hyacinths, Scillas, autumn Crocuses and others constitute the bulk of the Dutch bulb trade. The day lilies (*Hemerocallis*) merit special attention. *Asparagus* is an important vegetable crop. The onion and garlic are of great commercial value. The red squill, used in rodent control, is obtained from the bulbs of *Urginea*. *Aloin*, important in drug trade, is obtained from large acerage of the genus *Aloe*. *Colchicum* is an important medicinal plant. Many plants are used as ornamentals, such as *Gloriosa*, *Hemerocallis*, *Asphodelus*, *Dracaena*, *Yucca*, etc.

AMARYLLIDACEAE

General characters

Plants—mostly perennial herbs with bulbous, sometimes rhizo-

matous stems, rarely shrubby or arborescent. Leaves—radical. distichous. Inflorescence—monochasial cymes, subtended by 2-many spathe-like bracts and borne on a leafless scape. Flowers—regular or zygomorphic, bisexual, epigynous. Perianth—3+3, petaloid, sometimes gamophyllous with a corona (e.g., *Narcissus*,

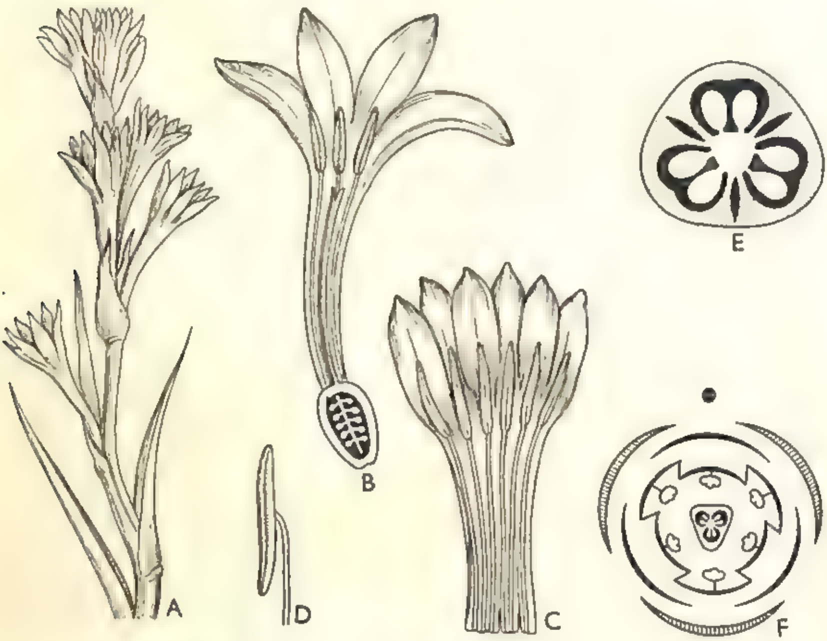


Fig. 503. Amaryllidaceae (*Polianthes tuberosa*).
A, Portion of a flowering shoot; B, V.s. of a flower; C, Perianth-tube split open showing epiphyllous stamens; D, Stamen; E, T.s. of ovary; F, Floral diagram.

Pancratium, some species of *Crinum*), united below into a shorter or longer tube, imbricate or valvate. Stamens—6, with introrse anthers, epiphyllous. Carpels—(3); *ovary inferior*, usually 3-celled with numerous anatropous ovules arranged in two series on axile placenta. Fruit—usually a 3-celled capsule, sometimes berry. Seeds—few to many. Embryo—small, embedded in a copious fleshy endosperm; radicle turned towards the hilum.

Number and distribution

This family consists of 86 genera and about 1,310 species confined to the warmer regions of both hemispheres. Chiefly xerophytic.

KEY TO GENERA

A. Leaves large, thick, fleshy, densely clustered at the top of a short stem, spiny at the tip and armed along the the edge.
   (*a*) Inflorescence simple, spicate or compound, thyrsoid; stamens longer than perianth .. .. *Agave*
   (*b*) Inflorescence laxly paniculate; stamens shorter than perianth .. .. *Furcraea.*

B. Leaves unarmed, thin, flat or somewhat fleshy:
   (*a*) Rootstock tuberous—
   Leaves large, lanceolate, plicate; fruit dehiscent .. *Curculigo.*
   (*b*) Rootstock a tunicated bulb: flowers white or pink, large, showy—
      (*i*) Filaments attached to perianth but not connate—
      Scapes 1-flowered .. .. .. *Zephyranthes.*
      Scapes umbellate .. .. .. *Crinum.*
      Scapes a long spike, perianth somewhat curved *Polianthes.*
      (*ii*) Filaments united by an interveining petaloid membrane .. .. *Pancratium.*

Range of floral structures

The plan of the flower in Amaryllidaceae resembles Liliaceae excepting the character of an inferior zygomorphic flower is often noted, as in *Alstroemeria*, by reduction of perianth, stamens and style. Perianth members are generally connate but free perianths are also found in *Galanthus*, *Leucojum*, etc. In *Galanthus*, the outer three perianth-segments become larger and spreading, whereas the inner ones are smaller and straight.The members of the perianth are 6, which generally form a longer or shorter tube.

The corona or paracorolla met with in many genera of this family exhibits the most exquisite and curious morphological structure. The so-called corona or paracorolla is supposed to be the basal outgrowth of the filaments which are united together to form funnel-shaped structure, or inner outgrowth of perianth constituting the infundibular structure. The corona is either staminal or perigonal from the view-point of origin. In *Narcissus* and *Cryptostephanus*, the nature of corona is perigonal but it becomes staminal in *Pancratium.* Considerable debate has been made about the nature of paracorolla and it has been interpreted by many authors, and according to others it has been considered as nectar-secreting disc.

Variation in the number of stamens is also noted. In the genus, *Gethyllis*, 12-18 stamens are found to be united in many bundles. In *Vellozia*, the number of stamens is some multiple of 6.

The ovary is usually 3-celled, but 1-celled ovary with parietal placentation is found in *Leontochir*.

Common plants

(1) Tuberose (*Polianthes tuberosa* L.), commonly cultivated in gardens for the sweet-scented white flowers. (2) *Crinum asiaticum* L.

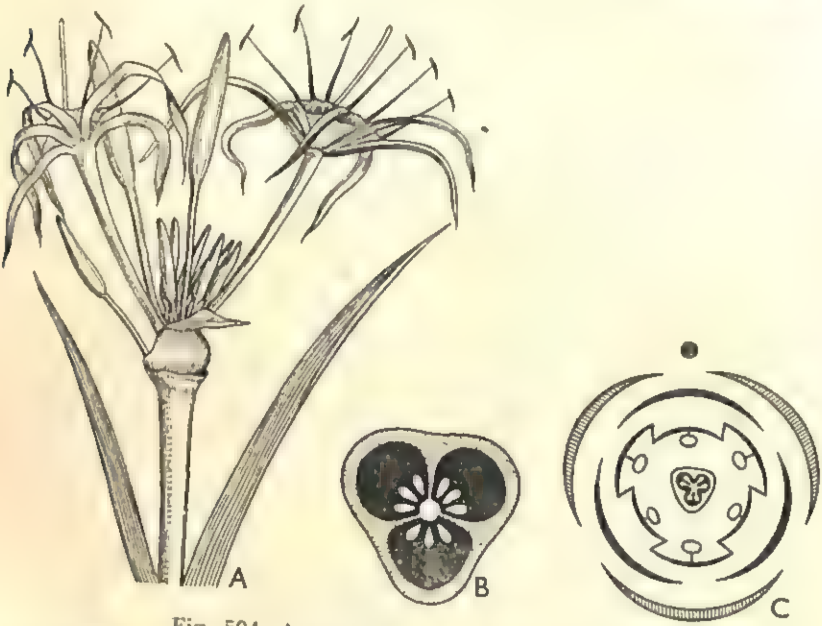


Fig. 504. Amaryllidaceae (*Crinum asiaticum*).
A, Portion of a flowering shoot; B, T.s. of ovary; C, Floral diagram.

and *C. latifolium* L., common garden plants with flowers in cymose umbels. (3) *Pancratium verecundum* Ait., another common garden plant with staminal coronas which are united forming a cup-like structure. (4) *Curculigo orchioides* Gaertn., a garden plant very common in dry situations with yellow flowers. (5) *Curculigo recurvata* Dryand., a native of the tropical Himalayas is found in Darjeeling; it is a highly interesting plant likely to be mistaken for a dwarf palm on account of its corrugated palm-like leaves. (6) *Agave americana* L. and *A. cantula* Roxb., commonly planted in gardens and along the railway lines for hedging purpose. (7) Star-grass (*Hypoxis*

aurea Lour.), a small weed with tubercled seeds. (8) Daffodil (*Narcissus pseudo-narcissus*), a common garden plant with prominent corona. (9) *Furcraea gigantea* Vent., a short-stemmed large shrub. (10) *Zephyranthes tubispatha* Herb., a bulbous herb of the gardens.

Affinity

This family is closely allied to Liliaceae but readily distinguished by the inferior ovary. It is also allied to Dioscoreaceae but the latter is distinguished by its habits: climbing plants with net-veined leaves and small, often unisexual flowers. Iridaceae, while resembling Amaryllidaceae in the inferior ovary, is distinguished from the latter as well as other epigynous petaloid families in having only three stamens.

Economic importance

This family is of some economic importance. *Agave americana* is one of the most important economic plants of Mexico and is widely cultivated in the tropics for the tough bast fibres of the leaf which yield the 'false manila hemp' of commerce; the sap which exudes from the terminal bud on removal yields, when fermented, a drink known as '*pulque*.' Other species are also useful fibre-plants, e.g., Sisal Hemp (*A. rigida* var *sisalana*). *Furcraea* is another fibre-yielding plant. The South American genus *Alstroemeria* yields a kind of flour from its root. Many plants are used as ornamentals, such as, *Crinum*, *Polianthes*, *Curculigo*, *Amaryllis*, *Narcissus*, *Pancratium*, *Zephyranthes*, etc.

ORDER 10. SCITAMINEAE

Generally large perennial herbs with rhizomatous stems; leaves distichous or in spirals, but the leaf-sheath is not entire; flowers bisexual, usually irregular; perianth in two trimerous whorls, petaloid or differentiated into calyx and corolla; functional stamens 1 or 5 (but 6 in *Ravenala*); carpels (3); ovary inferior, usually 3-celled, with 1-many ovules in each cell; fruit capsule or berry; seed with small endosperm and copious perisperm, embryo straight or curved.

According to Engler this Order comprises 4 families, viz., Musaceae, Zingiberaceae, Cannaceae, and Marantaceae. In Bentham and Hooker's system this Order is designated as family

Scitamineae consisting of 3 subfamilies Zingiberaceae, Cannaceae or Marantaceae and Musaceae and they have placed it under the series Epigynae. Hutchinson places the aforesaid families under the Order Zingiberales.

MUSACEAE

General characters

Plants—perennial large herbs with rhizomatous stems or rarely with woody stems (e.g., *Ravenala* and some species of *Strelitzia*). Leaves—large, glabrous, simple, lanceolate or oblong, entire, with

Fig. 505. Musaceae (*Musa sapientum*).
A, The plant; B, A spathe enclosing two rows of flowers; C, Flower; D, Calyx split open; E, T.s. of ovary; F, Floral diagram.

prominent midrib and sheathing leaf-base. Inflorescence—spadix enclosed by fleshy spathaceous bracts. Flowers—zygomorphic, usually bisexual, epigynous, often large and showy. Perianth—3+3, petaloid or distinguished into calyx and corolla, free or united. Stamens—5, only the posterior is rudimentary (staminode) or wanting, sometimes 6 perfect (e.g. *Ravenala*). Carpels—(3); ovary

inferior, 3-celled, with numerous ovules on the inner angle of each cell, but often they are suppressed by cultivation. Fruit—berry or capsule (e.g., *Ravenala*). Seeds—often arillate with mealy endosperm and with straight embryo.

Number and distribution

This family consists of 5 genera and about 150 species which are commonly distributed in the tropics of both the old and new worlds.

KEY TO GENERA

(*a*) Sepals free; petals long and narrow; stamens 6 perfect; stem tree-like, marked with annular leaf-scars; leaves distichous, very large; fruit capsule .. .. *Ravenala.*

(*b*) Sepals united into a split spathaceous tube; leaves spiral, oblong; stamens 5 perfect; fruit a berry .. .. *Musa.*

Common plants

(1) Plantain (*Musa paradisiaca* L.), commonly cultivated for unripe fruits, which are taken as vegetables and for disorder of the stomach. (2) Banana (*Musa sapientum* L.), commonly cultivated for delicious fruits. (3) *Musa textilis* Nees., fibres of which yield the 'manila hemp' of commerce. (4) Traveller's tree (*Ravenala madagascariensis* Sonn.), native of Madagascar often planted in gardens and is well-known for the exudation of watery sap from the petiole when incised.

Economic importance

The family is of some economic importance. *Musa sapientum* (banana) and *M. paradiasiaca* (plantain) are extensively cultivated for ripe and unripe fruits respectively. *M. textilis* yields a kind of fibre known as 'manila hemp' of commerce. Some plants are ornamentals, such as, *Ravenala madagascariensis* (traveller's tree), *Strelitzia reginae* Ait. (bird-of-paradise) and species of *Heliconia.*

ZINGIBERACEAE

General characters

Plants—perennial herbs usually with horizontal rhizomatous stems. Leaves—simple, with petiole, lamina and sheath; sheath bears a ligular outgrowth. Inflorescence—spike or raceme,

subtended by a bract. Flowers—medianly zygomorphic, bisexual, epigynous. Perianth—3+3, usually distinguished into calyx and corolla. Stamens—*only 1 fertile* (the median posterior one belonging

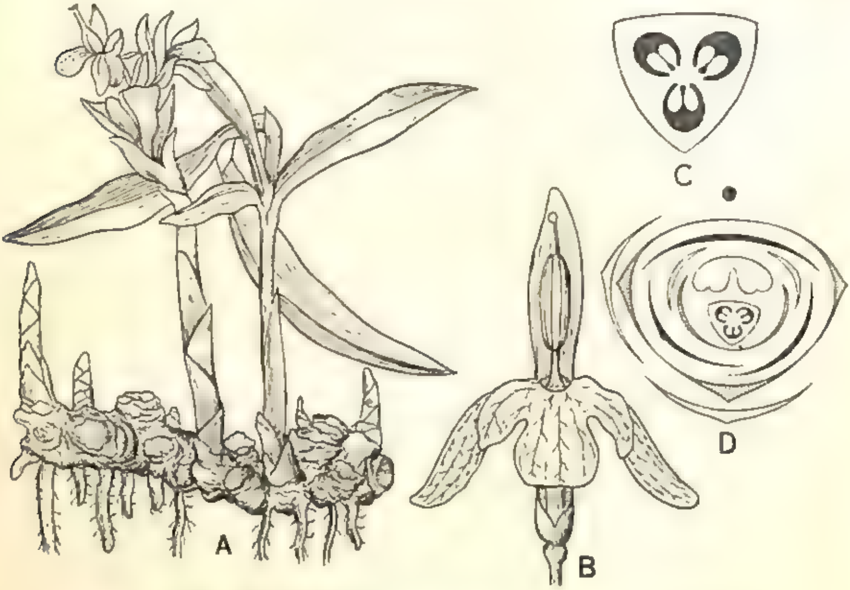


Fig. 506. Zingiberaceae (*Zingiber officinale*).
A, Portion of a plant; B, Flower; C, T.s. of ovary; D, Floral diagram.

to the inner whorl), 1 suppressed (the anterior one belonging to the outer whorl) and remaining 4 are converted into petaloid staminodes, of which 2 of the inner whorl are united forming the *labellum*, the landing stage of the insect. Carpels—(3); ovary inferior, 3-celled, rarely 1-celled (e.g., *Globba*), with many ovules in each cell. Fruit—capsule or berry. Seeds—generally arillate with straight embryo.

Number and distribution

This family consists of about 47 genera and 1,400 species which are distributed in the tropics and subtropics.

Key to Genera

A. Ovary 1-celled; stem leafy; flowers yellow; herbs with creeping rhizomes and erect stems; buds often replaced by bulbils .. .. *Globba.*

B. Ovary 3-celled with axile placentation—

(*a*) Lateral staminodes broad

(*i*) Connective not spurred at the base; corolla-tube long and slender

(1) Filaments short; connectives broad, crested; stem short with few leaves, or no aerial stem *Kaempferia.*

(2) Filaments long; connectives not crested; stem elongated, leafy .. .. *Hedychium.*

(*ii*) Connective spurred at the base; stemless herbs; leaves often very large; flowering spike surmounted by a coma of coloured bracts .. .. *Curcuma.*

(*b*) Lateral staminodes small or *O* or adnate to the lip

(*iii*) Flowering spikes dense cone-like, but not surmounted by a coma of bracts—

(3) Filaments short, not petaloid .. .. *Zingiber.*

(4) Filaments petaloid bearing the anther on its middle .. .. *Costus.*

(5) Filaments short, with or without petaloid crest .. .. *Amomum.*

(*c*) Flowers in racemes or panicles at the top of tall leafy stems .. .. *Alpinia.*

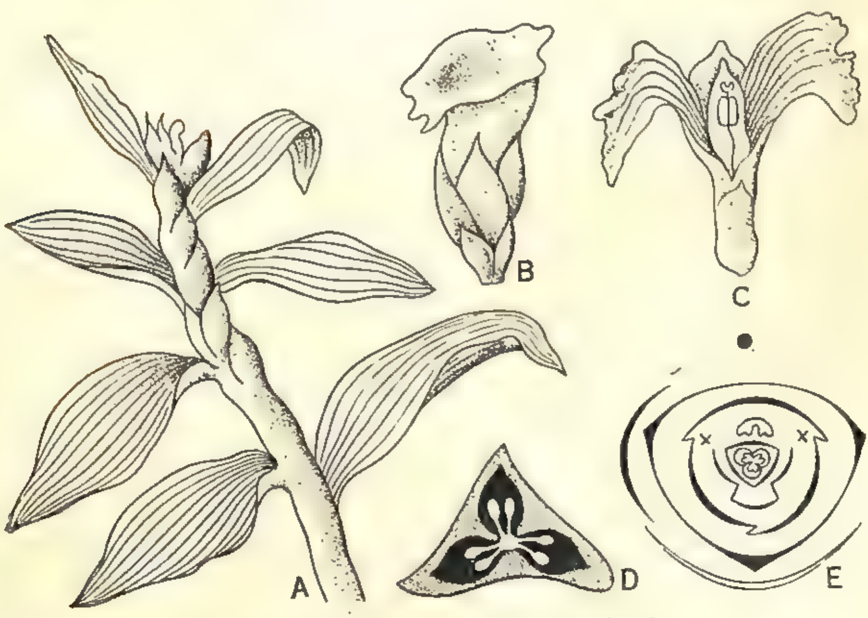


Fig. 507. Zingiberaceae (*Costus speciosus*).
A, Portion of a flowering shoot; B, Flower; C, Corolla split open; D, T.s. of ovary; E, Floral diagram.

Common plants

(1) Ginger (*Zingiber officinale* Roxb.), the dried rhizome of which yields the 'ginger' of commerce. (2) Mango ginger (*Curcuma amada* Roxb.), the rhizome of which has the smell of mango and hence used as a condiment. (3) Turmeric (*Curcuma longa* L. = *C. domestica* L.), the rhizome of which is used in cooking. (4) Indian arrowroot (*Curcuma zedoaria* Roscoe), the rhizome of which yields an inferior quality of arrowroot. (5) Ginger lily (*Hedychium coronarium* Koem.), commonly planted in gardens for its sweet-scented flowers. (6) *Kaempferia rotunda* L., another common garden plant with scented flowers. (7) Cardamon (*Amomum aromaticum* Roxb.), commonly cultivated in the hills for the sake of its seeds. (8) *Globba bulbifera* Roxb., common in marshy places and banks of rivers with terminal panicles, the lower flower buds of which are converted into bulbils which get easily detached and reproduce the plant. (9) Shell ginger (*Alpinia galanga* Sw.), a common garden plant with scented flowers. (10) *Costus speciosus* Smith, common in shady waste places.

Economic importance

This family is important economically. The rhizomes of ginger and turmeric are used in cooking and those of mango ginger in condiment. The seeds of cardamon are used medicinally as well as spice. Some plants are used as ornamentals, such as, *Hedychium*, *Kaempferia*, *Alpinia*, etc.

CANNACEAE

General characters

Plants—perennial herbs with rhizomatous stems. Leaves—large, simple, lanceolate, with prominent midrib and sheathing leaf-base. Inflorescence—spike. Flowers—asymmetrical, bisexual, epigynous, bracteate, large and showy. Perianth—3+3, distinguished into calyx and corolla. Stamens—*1/2 anther-lobe* of 1 stamen (the posterior) *fertile*, the other half is petaloid, 1 suppressed (the anterior), other 4 (2 outer and 2 inner) converted into petaloid staminodes, of which one of the inner whorl is the largest and forms the labellum. Carpels—(3); ovary inferior, 3-celled with numerous ovules in each cell; style petaloid; stigma terminal, oblique. Fruit—a capsule with warty or spinous projections. Seed—small, subglobose with very hard endosperm. Embryo—straight.

Number and distribution

This family consists of 1 genus and 30-60 species which are distributed in the tropics.

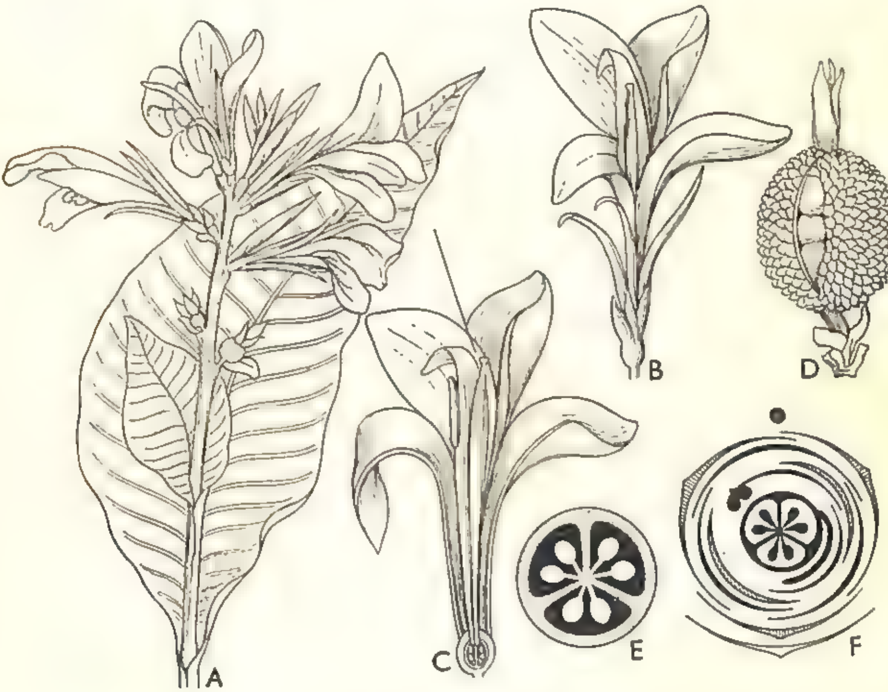


Fig. 508. Cannaceae (*Canna indica*).
A, Portion of a flowering shoot; B, Flower; C, V.s. of the same: D, Fruit; E, T.s. of ovary; F, Floral diagram.

Common plant

Indian shot (*Canna indica* L.), commonly cultivated in the garden for its showy flowers.

Economic importance

This family is of little economic importance. Different species of *Canna* are planted as ornamentals.

MARANTACEAE

General characters

Plants—perennial herbs with rhizomatous stems. Leaves—distichous, simple, with distinct petiole, lamina and sheath; a

pulvinus-like swelling is present below the lamina. Inflorescence—spicate cyme (monochasium) or panicle, usually subtended by spathe-like bracts. Flowers—irregular, bisexual, epigynous. Perianth—3+3, differentiated into calyx and corolla. Stamens—1/2 anther-lobe of 1 stamen (posterior) of the inner whorl perfect other half is a barren staminode, other members of this whorl are petaloid, of which one is *hooded*; the outer whorl is either entirely suppressed, or one or two petaloid staminodes are present. Carpels—(3); ovary inferior, 3-celled or apparently 1-celled with 1 ovule in each cell on axile placenta but appearing to be basal; style strong, flat and twisted; stigma is enclosed by an oblique, often lobed apex. Fruit—capsule or berry-like but dehiscent. Seeds—often arillate, albuminous. Embryo—curved.

Fig. 509. Floral diagram of *Maranta*.

Number and distribution

This family consists of 26 genera and about 350 species which are chiefly distributed in the tropics.

Key to Genera

(*a*) Ovary apparently 1-celled; 1 ovule with 2 empty cells; stem with a terminal few-flowered inflorescence .. *Maranta*.

(*b*) Ovary 3-celled, 3-ovuled; leafy stem with terminal panicled, scattered flowers; bracts and bracteoles deciduous .. .. *Clinogyne*.

Common plants

(1) Arrowroot (*Maranta arundinacea* L.), the rhizomes of which yield the 'arrowroot' of commerce. (2) Mat grass (*Clinogyne dichotoma* Salisb.), a cane-like plant, the split stems of which are woven into mats.

Economic importance

This family is economically important. *Maranta* yields the arrowroot of commerce. The split stems of *Clinogyne* are woven into

mats. Some plants are ornamentals, such as, *Maranta*, *Calathea* and *Thalia dealbata* (an aquatic plant).

Range of floral structures

The Musaceae approaches most nearly the common monocotyledonous arrangement. *Ravenala* has 6 fertile and equal stamens, and the zygomorphy of the flower is due merely to a small median petal. Generally, however, only 5 stamens are fertile, the sixth being absent or represented by a small petaloid structure. The flowers are rendered attractive by the large, often brilliantly coloured spathe-like bracts and also by the perianth. In *Strelitzia*, the united anterior petals form a landing stage for the honey-bird which visits the flower. The small tribe *Lowioideae* is of special interest from the orchid-like development of petals.

In the other families, the androecium plays the most important part in attracting the visitors and facilitating their entrance to the nectar-passage.

In Zingiberaceae, one stamen is fertile, but in Cannaceae and Marantaceae only half anther is functional, the rest of the stamens being more or less petaloid.

Marantaceae differs from other families in the reduction of the number of ovules, there being only one in each ovary-chamber, while frequently 2 of the 3 ovary-chambers become abortive so that only one-seeded fruit results.

ORDER 11. MICROSPERMAE

Flowers cyclic, usually irregular, bisexual; stamens adherent or adnate in whole or in part to the style; carpels 3; ovary inferior, 1-celled or 3-celled with numerous small ovules; fruit capsule; seeds very numerous, minute with an undifferentiated embryo and with or without endosperm.

According to Engler this Order comprises two families, *viz.*, Burmanniaceae and Orchidaceae*. Bentham and Hooker have designated this Order as a series and have placed it at the beginning of the monocotyledons. Hutchinson has separated the families of this order into two Orders, Burmaniales and Orchidales, containing the families Burmaniaceae and Orchidaceae respectively.

ORCHIDACEAE

General characters

Plants—perennial herbs, terrestrial or epiphytic, a few saprophytic deriving their nourishment from humus since their roots or rhizomes are associated with endotropic mycorrhiza. Roots—the main root is always absent, its place being taken by adventi-

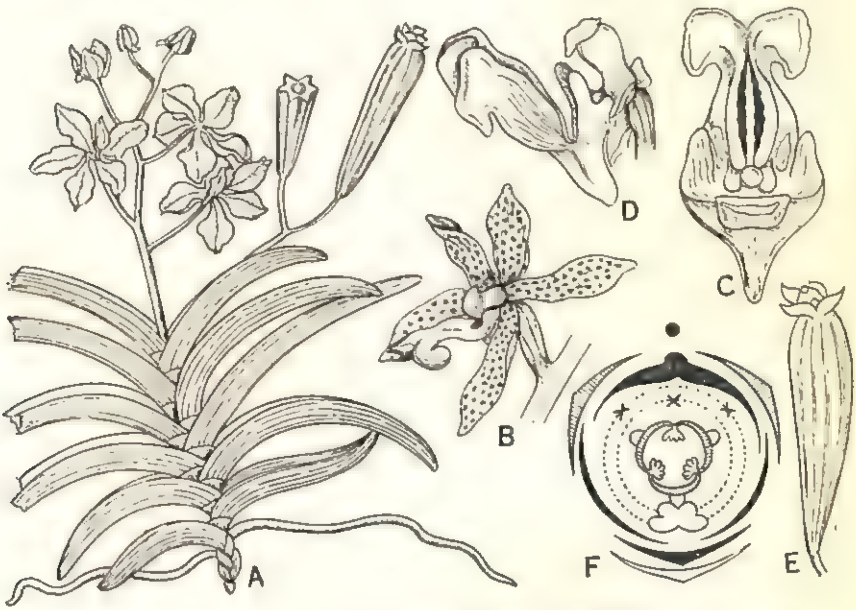


Fig. 510. Orchidaceae (*Vanda roxburghii*).
A, Portion of a shoot with flowers and fruits; B, Flower; C, Column; D, Back view of the same; E, Fruit; F, Floral diagram.

tious roots which arise especially from the nodes; they are generally of three kinds: (1) normal cylindrical earth-roots, (2) tuberous roots which serve for storage of reserve food materials and (3) aerial roots in which the epidermis is specially developed to form the *velamen*, special water-absorbing tissue, rarely absent. Inflorescence—raceme or spike. Flowers—bisexual, epigynous, medianly zygomorphic, usually very showy. Perianth—free, 3+3; the outer consisting of 3 sepals, more or less similar, and the inner of 3 petals, more or less dissimilar; the two lateral petals are alike and resemble the sepals but the median petal is usually much larger and known as the *labellum* or lip; the labellum is provided with a spur, variously shaped and normally posterior in position but

becomes anterior by the twisting of the ovary. Stamen—1 (in *Monandrae*) or 2 (in *Diandrae*); the filament is united with the style (gynandrous) forming a *column* or *gynostegium**; pollen grains granular, or powdery, more frequently united into masses called *pollinia*, 2-8 in number and each pollinium bears a cord, the *caudicle*, which ends in sticky discs or glands known as *retinacula*. Carpels—(3); ovary inferior, usually *twisted*, 1-celled with three double parietal placentae bearing many ovules;

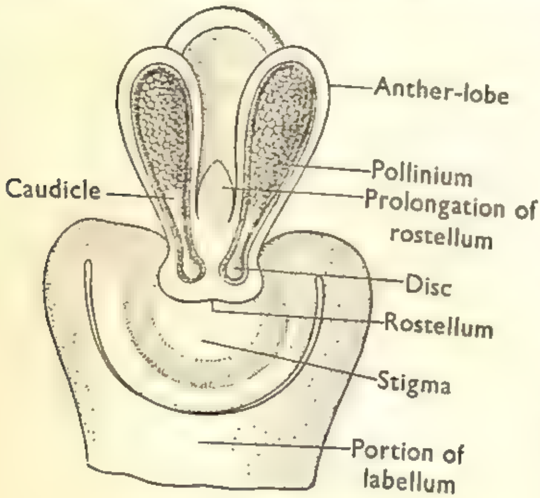


Fig. 511. Longitudinal section of an Orchid flower.

stigmas 3, sticky, situated below the rostellum and facing the labellum. Fruit—capsule. Seed—very numerous, minute, exalbuminous. Embryo—undifferentiated.

Number and distribution

This family consists of about 450 genera and 10,000-15,000 species widely distributed in the tropical and temperate regions of the world. This is the largest family of flowering plants in India. It is only in the E. Himalayas, Burma and Malaya Peninsula that the family predominates.

Key to Genera

(*a*) Terrestrial herbs with underground rhizomes; leaves elliptical, plicate, sheaths forming a pseudo-stem; lip white with pink lines or streaked with purple or red .. *Geodorum*.

*The construction of the column differs in the two suborders: in *Monandrae* the column bears an anther at the top and just under it there is a more or less projecting beak, the *rostellum* and under this there lies two fertile stigmas which are more or less united into one; but in *Diandrae* the three stigmas are united into one, on which the two anthers are placed and there is no rostellum. (The rostellum is only the projecting portion of the stigma; it is itself functionless but bends over and conceals the receptive portion of the stigmatic surface.)

(*b*) Terrestrial herbs, leafless, saprophytic, with tuberous roots; inflorescence a scanty raceme of white flowers .. *Didymoplexis.*

(*c*) Terrestrial 1-leaved tuberous herbs; leaf broadly cordate or orbicular, strongly plicate, lying on the surface of the ground; flowers on scapes arising from the tuber .. *Pogonia.*

(*d*) Terrestrial herbs with succulent glabrous stem; leaves membraneous, often withering at flowering times; flowers small, in recemes or spikes .. .. .. *Zeuxine.*

(*e*) Epiphytic herbs with leafy stems; leaves thickly coriaceous or fleshy, flat, keeled or terete; flowers large often showy in dense racemes or sometimes solitary; petals like sepals; lip large, base saccate or spurred; caudicle very broad .. *Vanda.*

(*f*) Epiphytic herbs; leaves coriaceous, flat, often keeled; flowers small in racemes, corymbs, umbels or panicles; petals like sepals; lip small, sessile, forms a cylindric or saccate spur; caudicle very narrow .. .. *Saccolabium.*

(*g*) Epiphytic herbs with pseudo-bulbs; leaves sessile, bases sheathing; flowers large and showy, solitary or in racemes; petals like the sepals; lip sessile or clawed at the base; anther 2-celled; pollinia 4, usually slightly coherent .. *Dendrobium.*

(*h*) Epiphytic shrub; stem terete or angled; leaves coriaceous or fleshy or *O*; pollinia granular .. .. *Vanilla.*

Range of floral structures

A wide variation occurs in the floral structures of this family. The sepals and petals may be quite different in form or they seem to be almost alike. The sepals are generally minute and indistinct but sometimes become somewhat conspicuous and larger, as in *Masdevallia*. The sepals may be free or more or less united. The odd sepal becomes spurred in *Disa*, but in *Haemaria*, it joins with the lateral petals forming hood-like structure.

Variation in the form of petals is also noticeable. The lateral petal is obliterated in *Coryanthes*, but in *Epicranthes* the petals are usually filiform. The petals become usually smaller than the lip, but sometimes become larger, as in *Oncidium*. In *Cypripedium*, the petals look like narrow ribbon and occasionally they are one yard long. In *Disa*, the labellum becomes sometimes minute and narrow or becomes large with spreading limbs, as in *Odontoglossum*, or they are curved, as in *Cattleya*. The labellum becomes slipper-like in *Cypripedium*, but in *Coryanthes* it assumes a bucket-like structure. The spurred petals may or may not be present. The origin of the spur is supposed to have been derived from the lip (labellum) or partly

from the floral axis. The incision of the lip may be various; it becomes either trifid or tripartite or the middle segment of the lip becomes 4-partite when re-divide or it may often represent the simplest type of lip which conform to the structure of the lateral petals, such as, in *Thelymitra*.

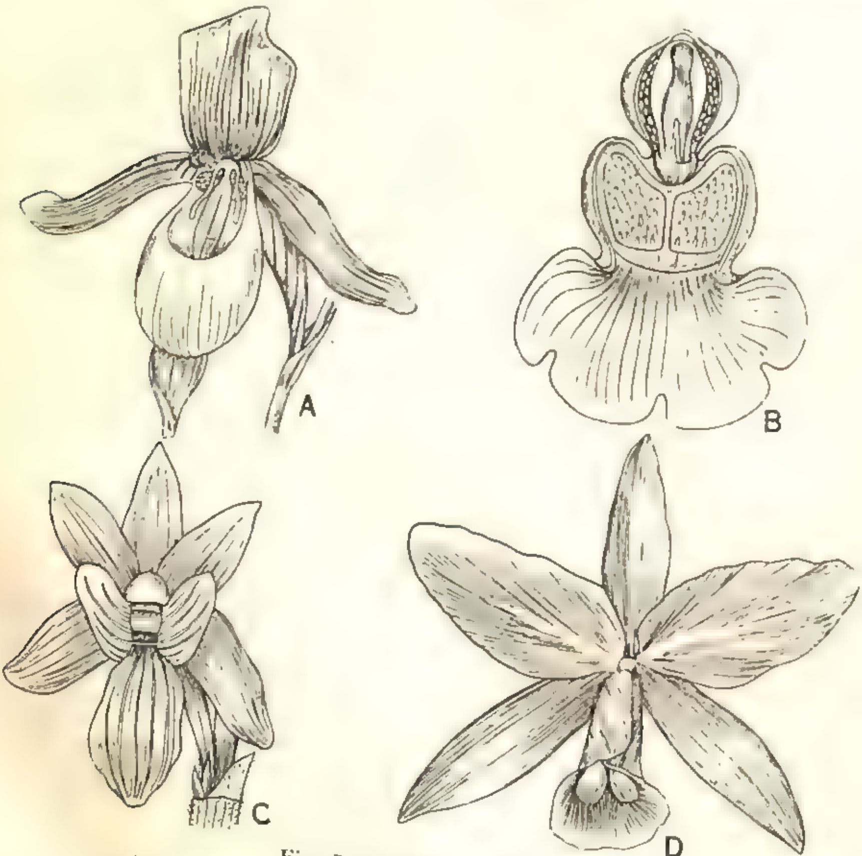


Fig. 512. Orchidaceae.
A, *Dendrobium*; B, *Orchis*; C, *Cypripedium*; D, *Cattleya*.

The odd member of the outer whorl of stamens, which is situated opposite the sepal, becomes generally fertile but a fleshy staminode is formed by that very stamen, as in *Cypripedium* and allied genera. In *Arundina pentandra*, they are found to be present and fertile, but in *Diuris*, they assume the form of leaf-like staminodes. In *Orchis*, they are represented by small auricles.

The lateral pair of the inner whorl of stamens becomes fertile, as in *Cypripedium*, but in others they form staminodes of different shapes, such as *Epipactis*, or are foliaceous, as in *Thelymitra*.

The anther may become erect and free on the top of the column, as in *Ophrys*, *Orchis* and others, but generally it becomes bent over the inner face of the latter. In *Coelogyne*, the anther seems to be hanged downwards vertically from the apex.

The union of column with anther may also vary. In the tribe Ophrydeae, it is provided with a broad, short filament from which it is quite unseparable. The anther remains strongly coherent with the column and it is not pulled off with the removal of pollen.

The anthers are either 2-, 4- or 6-chambered which correspond to the number of pollen-masses. Pollen-masses become either granular or powdery, as in *Cephalanthera*, or they are found to be united in packets by some sort of elastic net, as in *Orchis*, or waxy pollinia being united in a chamber are formed in *Cattleya*. A slender process is often formed by the drawing out of the lower part of the anther on each side and ultimately this process covers the lower sterile portion (caudicle) of the pollinium.

All three stigmas become functional in Cypripedeae and Apostasieae, but in some cases the lateral pair, the third being sterile and finally forms the rostellum. The stigmas originate as smooth, viscous, flat or cushion-like spots on the inner side, or sometimes on the end of the column, or often forms special processes that are carried up on the style-like projection, as in *Habenaria*.

The ovary manifests wide variations, but it is usually cylindrical or spindle-shaped. The ovary is often provided with longitudinal lines, ridges or wings which later on become more prominent with the ripening of the fruits.

The Orchids represent inferior and 1-locular ovary which bears numerous small ovules borne on three double parietal placentae.

Common plants

(1) *Vanda roxburghii* R. Br., an epiphytic herb commonly found on mango trees. (2) *Zeuxine sulcata* Lindl., a common terrestrial grass-like herb. (3) *Dendrobium* is found on the hills as well as in the Sundribans; *D. nobile* Lindl. is one of the noblest and finest specimens of the genus. (4) *Vanilla planifolia* L., cultivated for the fruits. (5) *Saccolabium papillosum* Lindl., epiphytic on trees. (6) *Pogonia plicata* Lindl. and *P. carinata* Lindl., common in shady thickets. (7) *Geodorum dilatum* R. Br., a terrestrial herb on grassy lawns. (8) *Didymoplexus pallens* Griff., commonly found in shady thickets.

Affinity

This family establishes a link with that of epigynous members of Liliflorae. Hutchinson considers the family to be derived from Haemodoraceae or Amaryllidaceae for higher and complex development of floral parts and the reduction of stamens during evolution. Moreover, the families Burmaniaceae and Apostasiaceae of the Order Orchidales resemble closely with those of epigynous Liliflorae. Orchidaceae is also supposed to have been derived from Musaceae based on the similar structure and construction of flowers of *Orchidantha* (a member of Musaceae) and a few genera of Orchids. On the whole, Orchidaceae represents the highest evolved family among the monocotyledons in the presence of floral complexity and general plan of construction.

There are certain reasons for considering Orchidaceae as one of the highest evolved family of monocotyledons. These are as follows—

(1) Zygomorphy of flowers accompanied with different types of labellum-formations along with spur containing nectar.

(2) Epigynous flowers.

(3) Constant reduction and suppression of the members of androecium.

(4) Reduction in the stigmatic lobes which often develop into rostellum.

(5) Diversity in shape and size of the flowers which may be of various types.

Economic importance

This family is less important economically. The roots of *Vanda* are used as curative for rheumatism and as an antidote for scorpion-stings. The dried pulpy fruit of *Vanilla planifolia* furnishes the 'vanilla' of commerce, used for flavouring chocolate and confectionary. Many species are cultivated as ornamentals, such as, *Cypripedium*, *Cattleya*, *Cymbidium*, *Dendrobium*, etc.

Comparison between Scitaminae and Orchidaceae

Scitaminae	*Orchidaceae*
(1) Plants—perennial herbs with rhizomatous stems.	(1) perennial herbs, terrestrial or epiphytic, a few saprophytic.

Scitaminae	*Orchidaceae*
(2) Roots—adventitious, one kind (earth-root).	(2) adventitious, 3 kinds—earth roots, fleshy tuberous roots and aerial roots with velamen.
(3) Leaves—large with prominent midrib and sheathing leaf-bases.	(3) thick and coriaceous.
(4) Inflorescence—spike or raceme with spathe-like bracts.	(4) raceme or spike.
(5) Flowers—usually bisexual, zygomorphic or asymmetrical, epigynous.	(5) bisexual, medianly zygomorphic, epigynous, gynandrous.
(6) Perianth—3+3, petaloid or distinguished into sepals and petals.	(6) 3+3, distinguished into sepals and petals; sepals similar, petals dissimilar, the median petal is the largest and forms the labellum.
(7) Stamens—1/2 or 1 or 5 (rarely 6), others converted into petaloid staminodes; one or two staminodes may form the labellum; pollen grains powdery.	(7) 1 or 2; pollen grains frequently united forming pollinia; filament united with the style forming a column.
(8) Carpels—(3); ovary inferior, 3-celled, with 1-many ovules in each.	(8) (3); ovary inferior, twisted, 1-celled with many ovules on parietal placentae.
(9) Stigma—variously developed.	(9) situated below the rostellum.
(10) Fruit—capsule or berry.	(10) capsule.

Comparison between Compositae and Orchidaceae

The Compositae and the Orchidaceae are regarded as the most highly developed families of the Dicotyledons and the Monocotyledons respectively, and as such a comparison of them is given below :

Compositae	*Orchidaceae*
(1) Plants—usually erect, terrestrial and autophytic annual herbs.	(1) usually trailing, epiphytic, parasitic or saprophytic perennial herbs.
(2) Roots—mostly true and normal; bundles tetrarch.	(2) mostly adventitious and epiphytic; bundles generally polyarch.

Compositae	*Orchidaceae*
(3) Stems—vascular bundles conjoint collateral, open and arranged in a ring.	(3) vascular bundles conjoint, collateral, closed and scattered.
(4) Leaves—usually simple with reticulate venation.	(4) simple with parallel venation
(5) Inflorescence—capitulum.	(5) usually raceme or spike.
(6) Flowers—individually minute, regular or irregular, neuter or unisexual or bisexual, pentamerous, epigynous, with reduced carpels.	(6) large, showy, irregular, bisexual; trimerous, epigynous, with reduced stamens.
(7) Calyx—absent or highly reduced.	(7) well-developed, sometimes brightly coloured.
(8) Corolla—gamopetalous.	(8) polypetalous.
(9) Androecium—stamens usually five in number; pollen grains distinct and powdery.	(9) stamens originally six in number, finally reduced to three, of which one or two become sterile forming staminodes; gynandrous, producing pollinia.
(10) Gynoecium—carpels (2), unilocular; ovary with basal placentation and a single anatropous ovule.	(10) carpels (3), tricarpellate, unilocular; ovary with parietal placentation and numerous anatropous ovules.
(11) Fruit—achene.	(11) capsule.
(12) Embryo—straight.	(12) undifferentiated.

CHAPTER IX

DICOTYLEDONS

These are plants which bear two cotyledons in their embryo. The radicle on germination produces a tap root. Leaves have reticulate venation. Flowers are usually pentamerous. Vascular bundles of the stem are open and arranged in a ring and those of the root di-, tri-, or tetrarch.

SUBCLASS ARCHICHLAMYDEAE

ORDER 1. VERTICILLATAE

Flowers monoecious. Male flowers verticillate. Stem anomalous anatomically. Fruit winged nut.

According to Engler Verticillatae is the 1st Order of Archichlamydeae as he regards it the most primitive one. Bentham and Hooker have placed Casuarinaceae in the series Unisexuales under subclass Monochlamydeae. Hutchinson has put the family under Casuarinales, the 49th Order of his system.

CASUARINACEAE

General characters

Plants—evergreen much-branched drooping trees or shrubs with *jointed whorled branches*, monoecious or dioecious ; internodes with striate grooves like that of *Equisetum*. Leaves—*minute, scale-like in whorl* of 4-16, usually linear to lanceolate, basaly united forming a sheath round the twig, exstipulate. Flowers—unisexual, naked ; male flowers verticillate in terminal spikes (catkin-like) and female flowers in ovoid or globose heads, subtended by bracts. Perianth—1 or 2, concave in male flowers but absent in female flowers. Stamens—in male flowers 1, subtended by 4 scale-like bracteoles. Carpels—in female flowers 2, subtended by 1 bract and a pair of bracteoles ; ovary superior, 2-celled but afterwards 1-celled bearing 2 ascending orthotropous ovules on a single *parietal placenta*; style 1, very short; stigma 2, long. Fruit—1-seeded winged nut, enclosed by 2 bracteoles and a bract; *many such fruits are aggregated into a dry, woody, cone-like , multiple fruit.*

Number and distribution

This family contains a single genus *Casuarina* with about 40 species. It is a native of Australia.

Common plant

Beef-wood tree (*Casuarina equisetifolia* Forst.), a tall tree planted usually in avenues.

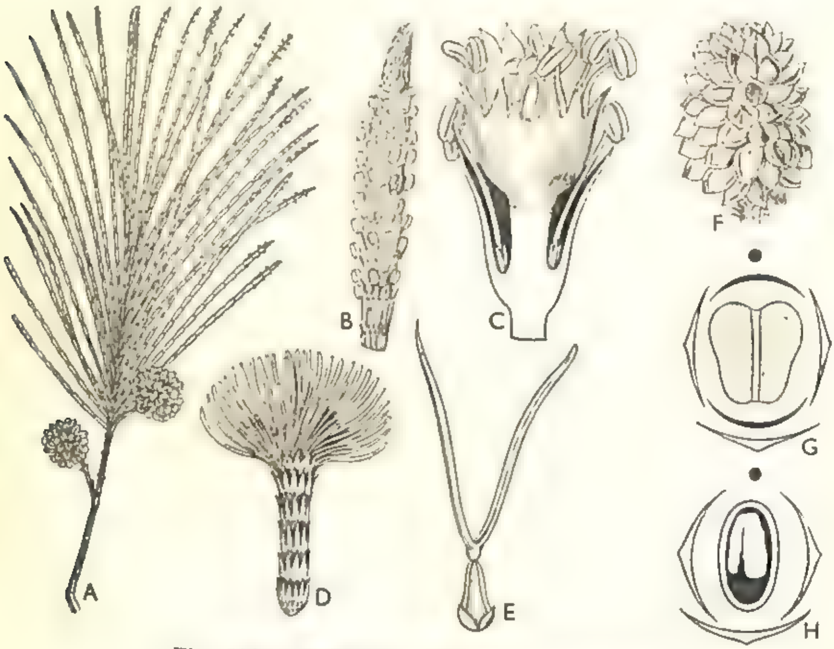


Fig. 513. Casuarinaceae (*Casuarina equisetifolia*).
A, Portion of a flowering shoot; B, staminate inflorescence; C, V.s. of a staminate flower; D, Pistillate inflorescence; E, Pistillate flower; F, Fruit; G, Floral diagram of staminate flower; H, The same of pistillate flower.

Affinity

Casuarinaceae resembles strikingly to the Betulaceae in the structure and development of the pistil and ovary. The characteristic stem and leaf of the genus *Casuarina* are highly adaptive but it is very difficult to ascertain any trace of affinity with the Fagales. The habit of *Casuarina* recalls the habit of *Ephedra*, a gymnosperm, thereby suggesting the derivation of gymnosperms from Casuarina-like primitive plant. This view has been propounded by Wettstein.

This family is readily distinguished from others by its equisetum-like jointed branches, whorled, minute leaves, and its woody cone-like fruit. Engler considers that the apparently simple anemophilous flowers, the approach to a catkin-like staminate inflorescence and the large rays in the wood of the family as a most primitive of dicotyledons.

Economic importance

Economically the family is important as a timber tree. Several species are cultivated extensively in our garden as ornamentals and also planted on the shores of India for afforestation.

ORDER 2. PIPERALES

Plants herbaceous. Leaves simple. Flowers in spikes or racemes, minute, usually bisexual, naked but often bracteate.

According to Engler Piperales is the second Order of Archichlamydeae. Bentham and Hooker have placed Piperaceae in the series Micrembryeae under subclass Monochlamydeae. In Hutchinson's system Piperales is the seventh Order of Dicotyledones.

The Order consists of four families : Saururaceae, Piperaceae, Chloranthaceae and Lecistemonaceae.

PIPERACEAE

General characters

Plants—erect or scandent herbs, or shrubs, with swollen nodes and more than one ring of *scattered vascular bundles* as in monocotyledons. Leaves—usually alternate, simple, often oblique, *fleshy*, exstipulate or with two adnate stipules. Inflorescence—*spike* (catkin). Flowers—*minute*, bisexual, sometimes unisexual (e.g., *Piper*), hypogynous, bracteate. Perianth—*absent*. Stamens—1-10; filaments usually distinct. Carpels—(2-5); ovary superior, *1-celled, with 1 basal orthotropous ovule;* style 0-1; stigmas 1-5 (often brush-like in *Peperomia*). Fruit—small drupe. Seed—*with endosperm and perisperm* and minute embryo.

Number and distribution

This family consists of about 10-12 genera and about 1,300 species, which are widely distributed in the tropics of both hemispheres.

Key to Genera

Fruit conspicuous, anther cells distinct, stigmas 3-5 confluent	*Piper.*
Fruit minute, anther cells confluent, stigma penicellate	*Peperomia.*

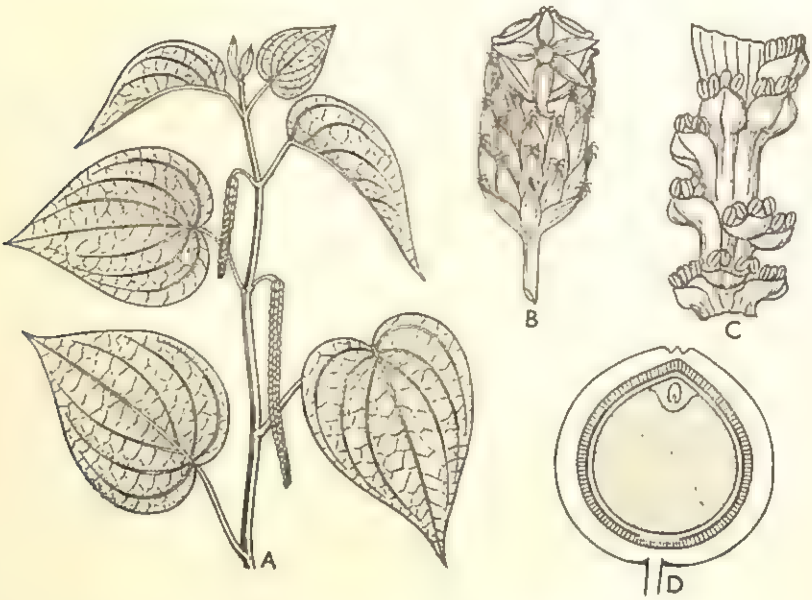


Fig. 514. Piperaceae (*Piper betle*).
A, Portion of a plant; B, Female inflorescence; C, Male inflorescence; D, L.s. of a seed.

Common plants

(1) Betle plant (*Piper betle* L.), a stout climber, cultivated largely for its leaves, which are used as a masticatory. (2) *P. chaba* Hunter, another stout climber, the wood of which is used as a pungent condiment. (3) Long pepper (*P. longum* L.), a slender creeper. (4) Black pepper (*P. nigrum* L.), another slender climber. (5) White pepper (*P. caninum*). (6) *Peperomia reflexa* A. D., a common herbaceous tufted weed of waste places.

Affinity

This family is readily distinguished by the presence of succulent habit, very minute naked flowers in spike inflorescence, and 1-celled ovary with solitary basal orthotropous ovule. Engler and Rendle believed that the family belonged to the most primitive dicotyledons.

But it is now generally held that the family has an indeterminate origin which may be an offshoot from ranalian ancestry.

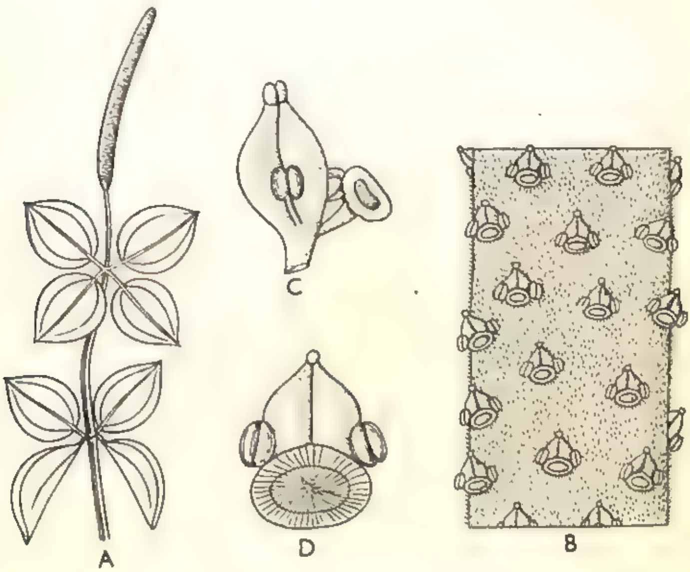


Fig. 515. Piperaceae (*Peperomia riflexa*).
A. Portion of a plant; B, A portion of a spike (enlarged);
C, V.s. of a flower; D, Flower.

Economic importance

This family is of great economic importance. Fruit of *Piper nigrum* and *P. caninum* are used as spice. *P. longum* is used in medicine. Some species are ornamental, such as *Macropiper*, *Piper*, *Peperomia*, etc.

ORDER 3. SALICALES

Flowers dioecious. Perianth absent. Bracteoles absent. Fruit capsule.

According to Engler this Order is also regarded as a primitive one and has been placed at the beginning. Bentham and Hooker have placed the family Salicaceae in the series Ordines anomali under the subclass Monochlamydeae. In Hutchinson's system Salicales comprises only 1 family, Salicaceae is the 43rd Order.

SALICACEAE

General characters

Plants—trees or shrubs, dioecious. Leaves—alternate, simple, vary from linear to cordate, stipulate. Inflorescence—*catkin*, erect or pendulous. Flowers—*unisexual*, sessile or shortly pedicellate, subtended by a hairy bract and a *cup-like disc* (an expanded floral axis), hypogynous. Perianth—*O*. Stamens—in male flowers 2 or more; filaments slender, free, or more or less united at the base, transversely placed. Carpels—in female flowers 2-4; ovary sessile superior, 1-celled with numerous anatropous ovules arranged on 2-4 *parietal placentae;* style short or long, lateral or antero-posterior to the carpel; stigma 2-4-fid. Fruit—a small *capsule* dehiscing by two valves. Seed—very small with a thin testa, exalbuminous, comose ; embryo straight.

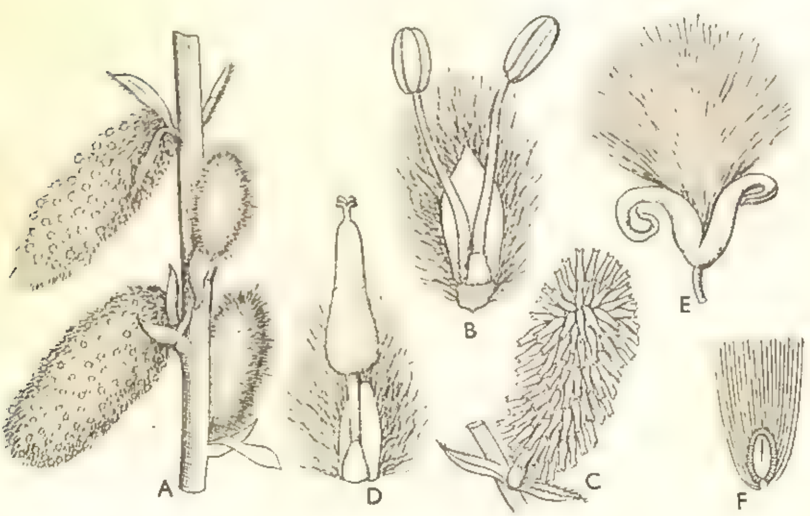


Fig. 516. Salicaceae (*Salix tetrasperma*).
A, Staminate catkins; B, Staminate flower; C, Pistillate catkin; D, Pistillate flower; E, Fruit; F, seed.

Number and distribution

This family consists of 2 genera and 300 species mostly confined to the temperate, alpine or artic zones.

Common plants

(1) Willow (*Salix tetrasperma* Roxb.) and (2) Poplar (*Populus alba* L.) are the common plants which are found on the hills.

KEY TO GENERA

Catkin pendulous, disc cupular or annular cut-bract ..	*Populus.*
Catkin erect, disc of 1 or 2 separate glands, entire bract	*Salix.*

Affinity

Engler considers this family to be primitive among the dicotyledons. This is partially supported by the presence of fossil remains straight from the tertiary age. Eichler, on the other hand, considers the members of the family arose as degenerated ones from complete, bisexual flowers. This family can be readily distinguished from the allied catkin-bearing families by dioceious plants, flowers subtended by hairy bracts and cup-like discs, and comose seeds.

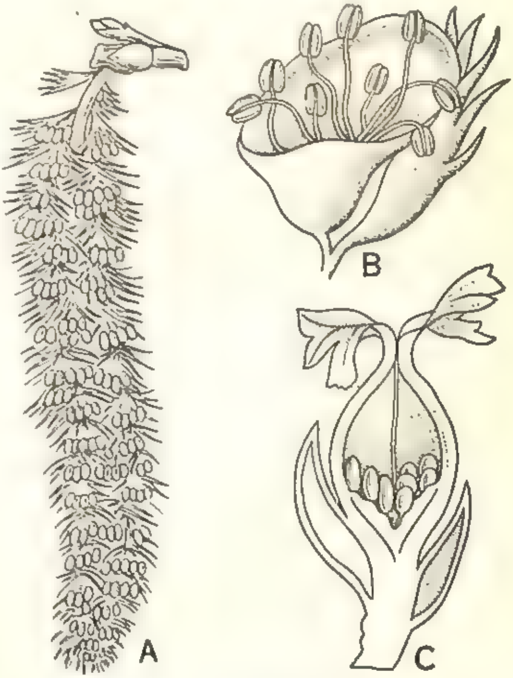


Fig. 517. Salicaceae (*Populus alba*). A. An inflorescence; B. Staminate flower; C. Pistillate flower.

Economic importance

This family is of little economic importance. Many species are ornamentals. The wood of *Salix* is used as a fuel and the twigs of Willows for basketry.

ORDER 12. URTICALES

Flowers generally unisexual. Stamens few to many. Ovary 2-

carpellate, superior, unilocular with a single ovule. Fruit a nut or drupe. Seed with fleshy or oily endosperm.

According to Engler this Order has been divided into 3 families: (*a*) Ulmaceae, (*b*) Moraceae and (*c*) Urticaceae. Bentham and Hooker have designated this Order as family Urticaceae under the series Unisexuales of Monochlamydeae and have divided it into 4 tribes: Urticeae, Cannabinae, Artocarpae and Moreae. Hutchinson, however, has divided this Order into 6 families: Ulmaceae, Urticaceae, Cannabinaceae, etc.; it occupies the 50th position.

MORACEAE

General characters

Plants—trees or shrubs, rarely herbs (e.g., *Dorstenia*), monoecious or dioecious, usually with *milky latex* (absent in *Cannabis* and *Humulus*). Leaves—alternate, simple, entire, serrate or lobed, stipulate. Inflorescence—condensed spike or cymose, sometimes hypanthodium (e.g., *Ficus*). Flowers—small, regular, *unisexual*, hypogynous. Perianth—usually 4 in two whorls, free or more less united, valvate

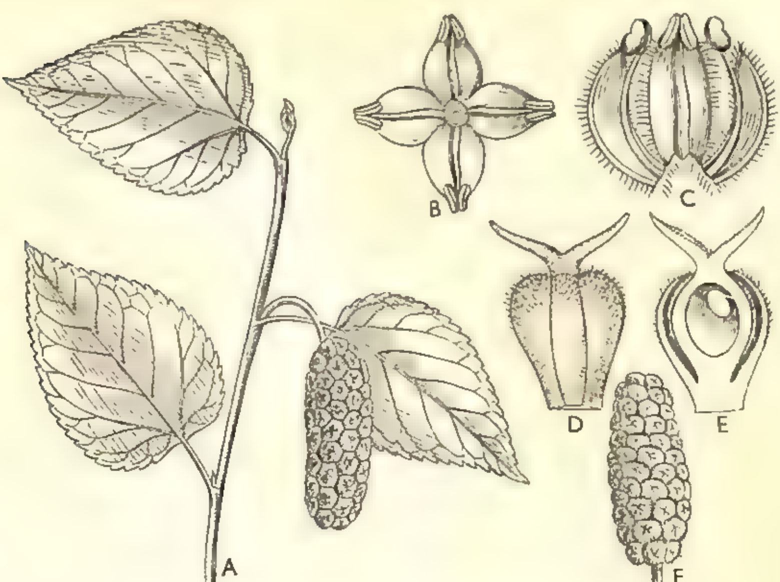


Fig. 518. Moraceae (*Morus indica*).
A, Portion of a flowering shoot; B, Staminate flower; C, V.s of the same D, Pistillate flower; E, V.s. of the same: F, Fruit.

or imbricate. Stamens—in male flowers generally equal in number and opposite the perianth-lobes, sometimes 2 or 1 (e.g., *Ficus*, *Morus*, *Artocarpus*, *Dorstenia*); filaments bent inwards in bud (e.g., *Morus*), but straight in *Ficus*. Carpels—in female flowers (2); ovary superior, usually *1-celled with 1 pendulous ovule in each ; stigma usually 2-fid*. Fruit—drupe, syconus (e.g., *Ficus*) or sorosis (e.g., *Artocarpus* and *Morus*). Seeds—with fleshy endosperm and curved embryo.

Number and distribution

This family consists of nearly 73 genera and over 1000 species, which are widely distributed in the tropics.

KEY TO GENERA

A. Trees or shrubs

(*a*) Male flowers spicate, female ones in globose head: style undivided: achenes stipitate: dioecious trees — *Broussonetia.*

(*b*) Male flowers in minute heads, female flowers solitary axillary; small trees with rigid and scabrid (both sides) leaves .. .. .. *Streblus.*

Flowers concealed inside fleshy receptacles .. *Ficus.*

Fig. 519. Moraceae (*Ficus pumila*).
A, Portion of a flowering shoot; B, L.s. of an inflorescence; C, Staminate flower, D, Staminode; E, Pistillate flower; F, L.s. of ovary.

Flowers covering the outside of fleshy receptacles .. *Artocarpus.*

(*c*) Leaves alternate, entire, toothed or 3-lobed; flowers monoecious, male spikes elongated, female spikes long cylindric, or short oblong, or nearly globose; style divided .. .. .. *Morus.*

B. Tall erect herb

Leaves opposite below, alternate above, lanceolate, serrate; stipules 2, lateral; flowers dioecious .. *Cannabis.*

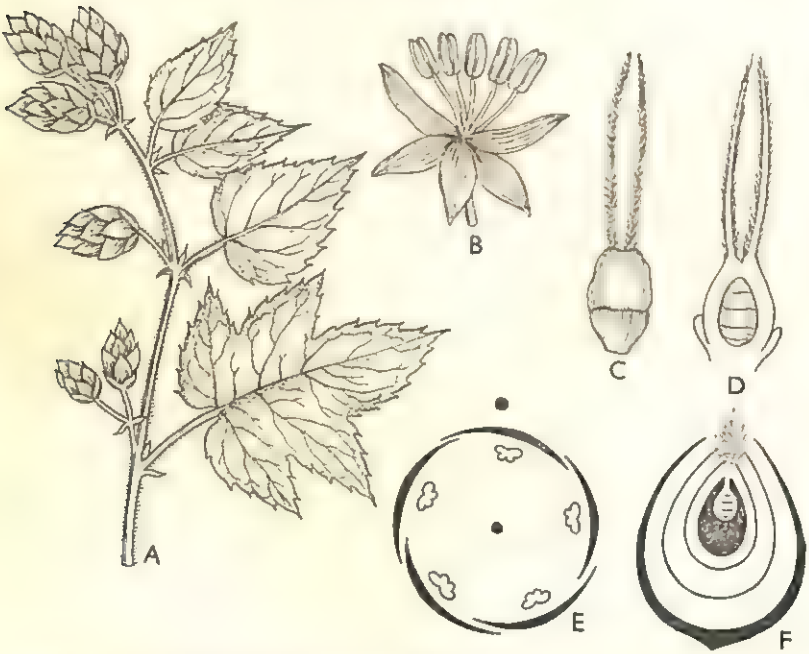


Fig. 520. Moraceae (*Humulus lupulus*).
A, Portion of a flowering shoot, B, Staminate flower; C, Pistillate flower; D, V.s. of the same; E, Floral diagram of staminate flower; F, Same of pistillate flower.

Common plants

(1) Banyan tree (*Ficus benghalensis* L.). (2) Peepul tree (*Ficus religiosa* L.). (3) Fig tree (*Ficus cunia* Ham., *Ficus hispida* L. f.). (4) *F. infectoria* Roxb. = *F. lacor* Buch-Ham. (5) Ivy fig (*Ficus stipulata* Wall.), a common herb found climbing on walls. (6) India Rubber tree (*F. elastica* Roxb.). (7) Jackfruit tree (*Artocarpus integrifolia* L. = *A. heterophyllus* Lamk.). (8) Breadfruit tree (*A. incisa* L. f.), a native of Sunda islands, occasionally planted in gardens. (9) Monkey jack (*A. lakoocha* Roxb.), another fruit-tree. (10) Mulberry

(*Morus indica* L.), chiefly cultivated for rearing silkworms. (11) Paper Mulberry (*Broussonetia papyrifera* Vent.), occasionally cultivated, the bark of which is chiefly used for manufacturing paper. (12) *Streblus asper* Lour., a rigid shrub found on roadsides. (13) Hemp (*Cannabis sativa* L.), a tall erect annual herb. (14) Hop (*Humulus lupulus* L.), a shrub cultivated in gardens.

Affinity

This family is readily distinguished from other families of the Order by the stinging hairs (when present) and milky latex, monocarpellary ovary with a single style, usually 2 stigmas, pendulous single ovule, and the cymose inflorescences on short axillary shoots. It can be distinguished from Euphorbiaceae by the simple ovary.

Economic importance

This family is economically important. Species of *Ficus*, *Morus*, *Artocarpus* yield edible fruits. A good quality of timber is obtained from *Artocarpus integrifolia*. *Cannabis* yields fibres for cordage and a narcotic product known as hemp*. *Ficus elastica* yields caoutchouc. The inner bark of *Broussonetia* is used for making paper. The fruit of Hop is used in flavouring beer. Some plants are used as ornamentals, such as *Ficus*, *Cecropia*, *Chlorophora*, *Cudrania*, *Dorstenia*, etc.

URTICACEAE

General characters

Plants—usually herbs, rarely small trees (e.g., *Holoptelea*), with *watery latex*, and sometimes with *stinging hairs*, monoecious or dioecious. Leaves—alternate or opposite, simple, usually stipulate. Inflorescence—cymose, sometimes catkin-like (e.g., *Boehmaria*), on short axillary shoots. Flowers—small, green, regular, *unisexual*, hypogynous. Perianth—4 in two whorls, free in male flowers but more or less united in female flowers, persistent. Stamens—in male flowers usually 4, opposite the perianth-leaves; filaments *bent inwards in bud*, but when mature spring elastically backwards and outwards discharging cloud of pollen. Carpel—in female flowers 1;

* The leaves of this plant are used in preparing an intoxicating beverage known as 'bhang'; the young inflorescences are smoked as 'ganja', and the resinous exudation is also smoked as 'charas'.

Urticales as evidenced by the abortion of the second carpel, basal position of the ovule and herbaceous habit. It is distinguished from other families of the Order by the stinging hairs (when present), monocarpellary ovary with single basal orthotropous ovule, single style and cymose inflorescences on short axillary shoots.

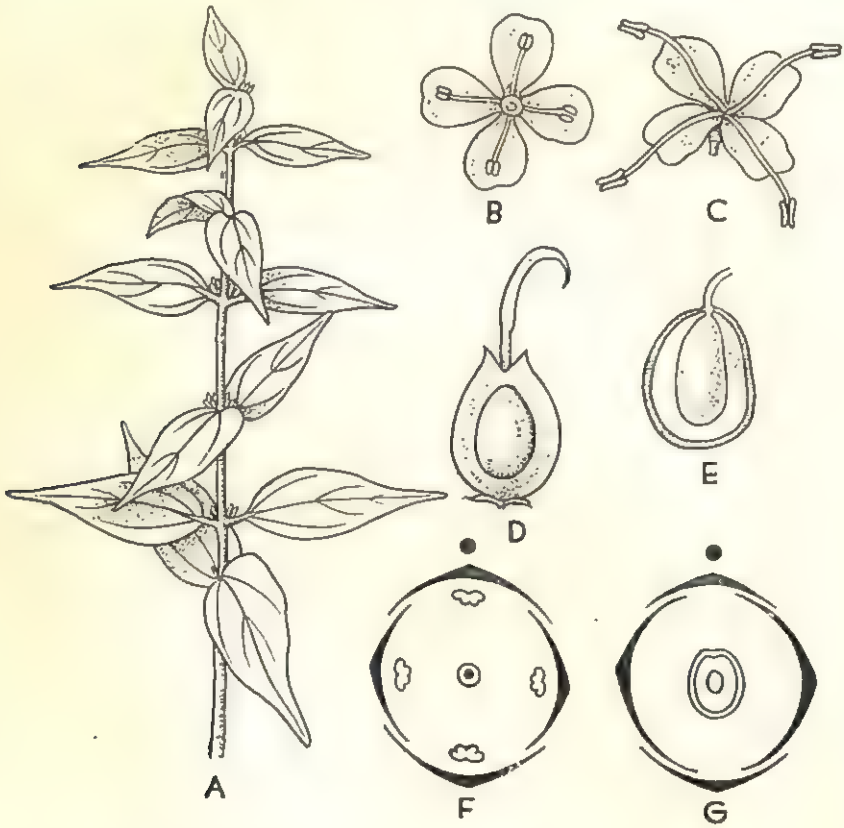


Fig. 523. Urticaceae (*Pouzolzia indica*).
A, Portion of a flowering shoot; B, A young staminate flower; C, An old staminate flower; D, Pistillate flower; E, L.s. of ovary; F, Floral diagram of staminate flower; G, Same of pistillate flower.

Economic importance

This family is of little economic importance. *Boehmaria* furnishes fibre for Chinese 'grass cloth' known as Ramia. Species of *Pilea*, *Pellionia*, etc., are ornamentals.

ORDER 14. SANTANALES

Flowers usually unisexual, cyclic, regular, sometimes irregular. Perianth leaves small and opposite to the adnate stamens. Stamens isomerous. Carpels (2-3), ovary unilocular with few pendulous ovules. Fruit a one-seeded nut, or a drupe, or a berry-like pseudocarp. Seeds with endosperm and a straight embryo.

According to Engler this Order has been divided into 3 suborders: (*a*) Santalineae, (*b*) Loranthineae and (*c*) Balanophorineae which contain 3 families, Santalaceae, Loranthaceae and Balanophoraceae respectively. In Bentham and Hooker's system there is no such Order, the families Loranthaceae and Santalaceae have been placed under the series Achlanydosporeae of the subclass Monochlamydeae. In Hutchinson's system it is the 50th Order and consists of 6 families.

SANTALACEAE

General characters

Plants—small trees or shrubs or herbs, semi-parasitic on roots. Leaves—usually opposite, simple, sometimes scale-like or *O*, exstipulate. Inflorescence—various, usually cymose panicles in the axils of leaves and at the ends of the branches. Flowers—small,

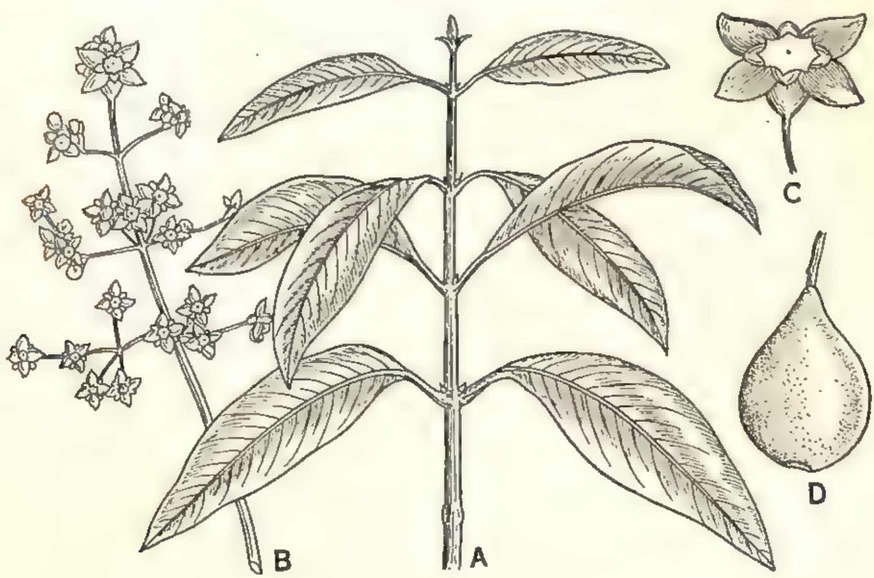


Fig. 524. Santalaceae (*Santalum album*).
A, A vegetative shoot; B, An inflorescence; C, Flower; D, Fruit.

regular, bisexual or unisexual by reduction, epigynous or hypogynous, usually with *nectar-secreting glands*. Perianth—4-5, simple, sepaloid or petaloid, united below into a tube, valvate. Stamens —4-5, opposite to the perianth leaves and are attached to the base or on the perianth-tube; tufts of hairs are present just behind each stamen. Carpels—3-5; ovary inferior, sometimes superior (e.g., *Santalum*), 1-celled with *central placenta* bearing usually *3 ovules, each with 1 integument*. Fruit—a drupe or an achene. Seed—*without testa*, albuminous; embryo straight.

Number and distribution

The family consists of about 26 genera with 250 species widely distributed in the tropics.

Common plant

The Sandal wood tree (*Santalum album* L.), common in South India and often planted in gardens.

Affinity

This family is closely allied to Loranthaceae but readily distinguished by the presence of central placenta, 3-5 carpellate ovary with 3 ovules, ovule with one or no integument, and the seed without testa.

Economic importance

This family is less important economically. *Santalum* yields the 'Sandal wood'. Only *Buckleya* and *Pyrularia* are ornamentals.

LORANTHACEAE

General characters

Plants—*hemi-parasitic herbs* with sympodial (but dichasial in *Viscum*) stems attached to the hosts by haustoria. Leaves—usually *opposite*, simple, entire, leathery, persistent, exstipulate. Inflorescence—solitary or dichasia in the axils of leaves. Flowers—almost regular, bisexual or unisexual and dioecious (e.g., *Viscum*), epigynous. Perianth—generally of two similar 2-3-merous whorls, free or united into a tube which is *often split down one side*, sepaloid (e.g., *Viscum*) or petaloid (e.g., *Loranthus*); in the latter a slightly

toothed or irregular rim (**calyculus**) is present below the perianth. Stamens—*isomerous* and opposite to perianth leaves, epiphyllous. Carpel—(3-4): ovary inferior, probably 1-celled with a large central placenta and *undifferentiated ovules*, of which usually only one attains maturity. Fruit—*pseudocarp* (ovary fused with the receptacular cup to form a berry or drupaceous fruit), pericarp membraneous or crustaceous. Seed—without testa, albuminous; embryo straight, large.

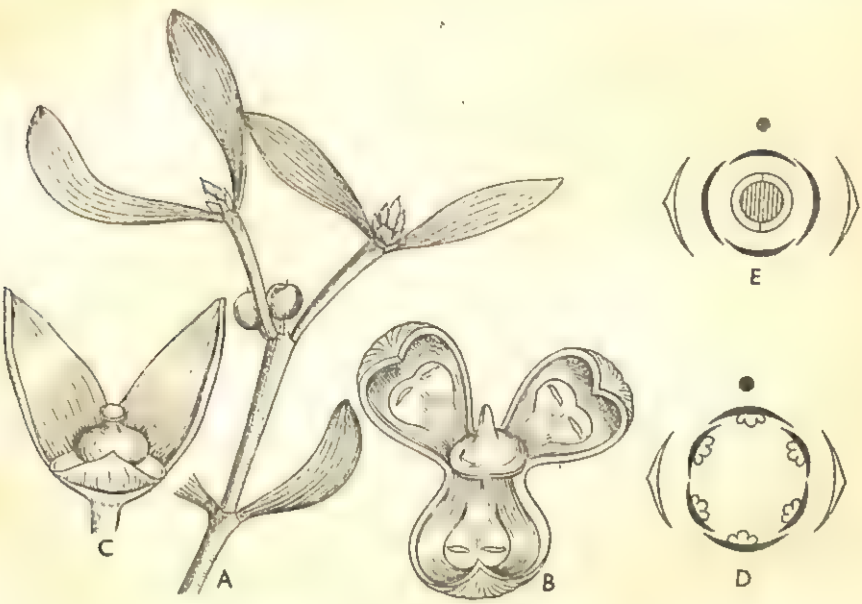


Fig. 525. Loranthaceae (*Viscum album*).
A, Portion of a flowering shoot; B, Staminate flower; C, Pistillate flower; D, Floral diagram of a staminate flower of the terminal dichasium; E, Same of pistillate flower.

Number and distribution

This family consists of 21 genera and over 500 species, mostly distributed in tropical and subtropical regions.

KEY TO GENERA

Fls. bisexual, calyculus present	*Loranthus.*
Fls. unisexual, calyculus absent	*Viscum.*

Common plants

(1) Mistletoe (*Viscum album* L.) and (2) *Loranthus longiflorus*

Deser. = *Dendrophthoe falcata* Etting. and *L. globossus* Roxb. are commonly found on mango trees.

Affinity

This family is related to Santalaceae in their habit, undifferentiated ovules and anomalous development of embryosac, but readily distinguished from it by the aerial parasitic habit, nature of the perianth, number of carpels, cup-shaped receptacle, absence of distinct ovules, and character of fruit.

Economic importance

Economically this family is not important.

ORDER 16. POLYGONALES

Plants herbs, shrubs or rarely trees. Leaves usually with ochreate stipules. Flowers bisexual consisting of similar members of perianth. Ovary 2-4-carpellate, superior, 1-celled with solitary orthotropous ovule. Fruit a nutlet or achene.

According to Engler this Order contains a single family Polygonaceae. Bentham and Hooker have put this family along with Nyctaginaceae, Amaranthaceae and Chenopodiaceae in the series Curvembryeae under the subclass Monochlamydeae. In Hutchinson's system it is the 18th Order and consists of 2 families.

POLYGONACEAE

General characters

Plants—usually herbs *with swollen nodes*, sometimes climbing (e.g., *Antigonon*), seldom trees (e.g., *Coccoloba uvifera*). Leaves—alternate, simple, usually with *ochreate stipules* (absent in *Antigonon*). Inflorescence—mixed in most cases, commonly a raceme or panicle of cymes. Flowers—small, regular, usually bisexual, trimerous, cyclic or acyclic. Perianth—3-6, free, green, sometimes petaloid, persistent. Stamens—6-9. Carpels—(3), rarely (2), united; ovary *triangular, 1-celled with 1 basal orthotropous ovule;* style 1; stigma, 2-4. Fruit—triangular or biconvex nut. Seed—with mealy endosperm. Embryo—curved.

Number and distribution

This family consists of about 32 genera and about 800 species which are chiefly found in the north temperate zone.

KEY TO GENERA

A. Inflorescence ending in a tendril, stipule 0
Perianth 5-cleft; climbing plant .. .. *Antigonon.*

B. Inflorescence not ending in a tendril, stipulate

(*i*) Perianth 4-5; capitate stigmas .. .. *Polygonum.*

(*ii*) Perianth 6-fid, inner 3 usually enlarged in fruit; stigmas horse-shoe shaped or peltate, fimbriated .. .. *Rumex.*

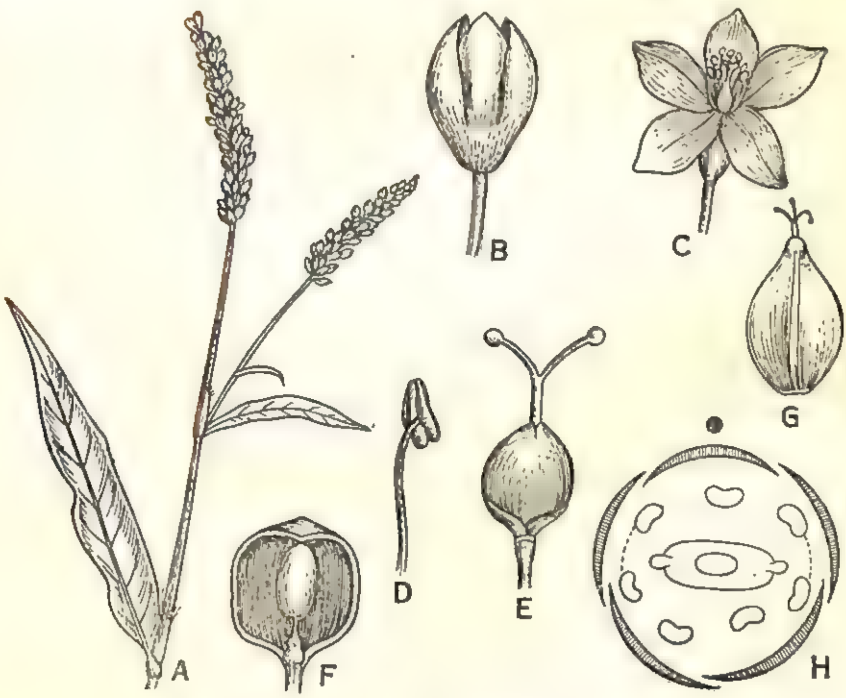


Fig. 526. Polygonaceae (*Polygonum orientale*).
A, Portion of a flowering shoot; B, Flower bud; C, Flower; D, Stamen; E, Pistil; F, L.s. of ovary; G, Fruit; H, Floral diagram.

Common plants

(1) Knot-weed (*Polygonum hydro-piper* L.), a common weed of damp places. (2) *Polygonum orientale* L. and *P. barbatum* L. are common

weeds of ditches. (3) *Polygonum plebejum* R. Br., a diffusely branched prostrate herb. (4) *Rumex maritimus* L., a marshy weed. (5) Dock (*Rumex vesicarius* L.) commonly cultivated for its acid leaves. (6) Railway creeper (*Antigonon leptopus* Hook. & Arn. = *Corculum leptopus* Stuntz.), a common garden climber with small pink or white flowers. (7) *Muehlenbeckia platyclada* Meisn. and *Coccoloba platyclada* Ham., are often planted in gardens for flattened leaf-like stems (phylloclades). (8) Sea grape (*Coccoloba uvifera* L.), a tree found in the Indian Botanic Garden, the leaves of which resemble *Ficus benghalensis* and likely to be mistaken for it. (9) Rhubarb (*Rheum emodi* Wall.), a medicinal plant commonly found in the hills.

Affinity

This family is closely allied to Chenopodiaceae, Amaranthaceae and Nyctaginaceae but readily distinguished by the ochreate stipules, triangular 1-celled ovary, with solitary basal ovule, 1-seeded fruit and curved embryo.

Economic importance

This family is not much important economically. *Fagopyrum* (buckwheat) and *Rheum* (rhubarb) are useful as food in the western countries. *Rheum emodi* is used in medicine. Some plants are also recognized as ornamentals, such as, *Antigonon*, *Coccoloba uvifera*, *Polygonum aubertii*, etc.

ORDER 17. CENTROSPERMAE

Plants annual and perennial herbs with alternate or opposite exstipuiate leaves. Flowers bisexual or unisexual by reduction, usually pentamerous. Perianth typically biseriate. Stamens in 1 or 2 series, hypogynous, or sometimes perigynous. Carpels with monocarpellary to pentacarpellary pistil; ovary superior, unilocular with 1-many campylotropous ovules. Fruit a capsule or nut, rarely baccate. Embryo large and curved or coiled.

According to Engler this Order consists of 4 suborders containing families Chenopodiaceae, Amaranthaceae, Nyctaginaceae, Portulacaceae, Caryophyllaceae, etc. Bentham and Hooker have put the families Nyctaginaceae, Amaranthaceae and Chenopodiaceae under the series Curvembryeae of subclass Monochlamydeae, and

Caryophyllaceae and Portulacaceae under the series Thalamiflorae of subclass Polypetalae. Hutchinson, however, has discarded the name of this Order and has placed Caryophyllaceae and Portulacaceae under the Order Caryophyllales (17th Order) and the rest under the Order Chenopodiales (19th Order).

CHENOPODIACEAE

General characters

Plants—usually annual or perennial succulent herbs, or shrubs, monoecious or dioecious with swollen nodes. Leaves—alternate, sometimes opposite (e.g., *Salicornia*), simple, fleshy, entire or variously lobed (but in halophytic species, such as *Suaeda, Salsola, Salicornia*,

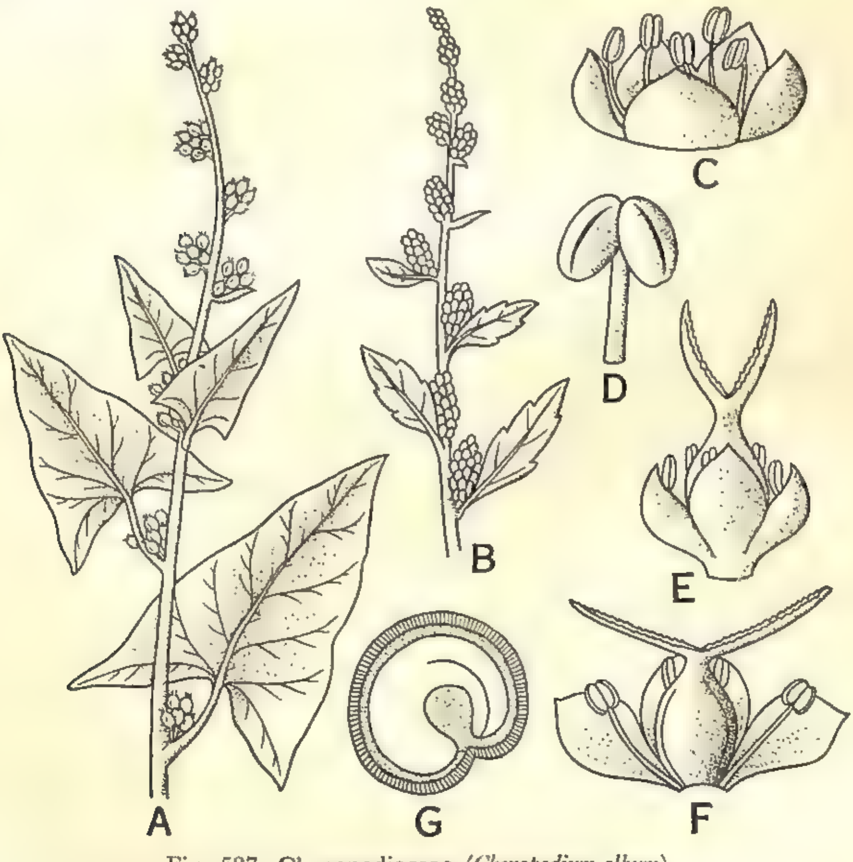


Fig. 527. Chenopodiaceae (*Chenopodium album*).
A, Portion of a flowering shoot bearing staminate flowers; B, The same with pistillate flowers; C, Staminate flower; D, Stamen; E, Pistillate flower; F, Hermaphodite flower; G, T.s. of seed.

etc., are much reduced in size, linear or even scale-like), glabrous (but covered with mealy hairs in *Chenopodium*, *Artiplex*, *Salsola*), *exstipulate*. Inflorescence—dense spike or panicle or cymose (at first dichasia but soon change into monochasia). Flowers—regular, bisexual (but unisexual in *Spinacia* and *Artiplex*), hypogynous (but epigynous in *Beta*), often with scarious bracts and bracteoles. Perianth—5, usually more or less dry and membraneous, free or more or less united, persistent. Stamens—5 (but 2 in *Salicornia*), *opposite the perianth leaves;* filaments united at the base into a short tube. Carpels—(2-3); ovary superior, sometimes inferior (e.g., *Beta*), *1-celled with a campylotropous erect or pendulous ovule;* style short or long; stigma usually 2-3-fid. Fruit—lens- or kidney-shaped nutlet. Seeds—albuminous or exalbuminous with hornyt esta; *embryo curved* (e.g., *Chenopodium*, *Artiplex*, *Salicornia*, *Beta*, etc.) or *coiled* (e.g., *Suaeda*, *Salsola*, etc.).

Number and distribution

This family consists of about 102 genera and 1,400 species which are cosmopolitan.

Key to Genera

A. Stem not jointed
- (*a*) Leaves fleshy; fls. minute, axillary, 2-sexual; stamens almost hypogynous .. .. .. *Suaeda.*
- (*b*) Leaves membraneous; fls. clustered; stamens perigynous
  - (*i*) Fls. all similar, 2-sexual
    - Perianth 5-partite, hardly altered in fruit; fls. without bracts and bracteoles .. *Chenopodium.*
    - Perianth 5-lobed, base thickened in fruit; fls. bracteate .. .. .. *Beta.*
  - (*ii*) Fls. dissimilar, 1-sexual
    - Male fls. in terminal spike; stamens 4-5; female fls. in axillary clusters, with 2-4 toothed perianth but without bracteole .. *Spinacia.*
    - Male fls. with 3-5 sepals; female fls. without perianth .. .. .. *Artiplex.*

B. Stem jointed; leaves *O;* fls. bisexual
- Fls. 2-6 in spike; perianth-mouth narrow, 3-4-fid .. *Arthrocneum.*
- Fls. in 3, sunk in cavities near joints; perianth-mouth wide, truncate or with 3-4 minute teeth .. *Salicornia.*

Common plants

(1) Spinach (*Spinacia oleracea* L.) commonly cultivated. (2) Lamb's quarters (*Chenopodium album* L.) and *C. ambrosoides* L., tall herbs which are also cultivated. (3) *Suaeda maritima* Dumort, commonly found in saline regions. (4) Salt bush (*Artiplex hortensis* L.).

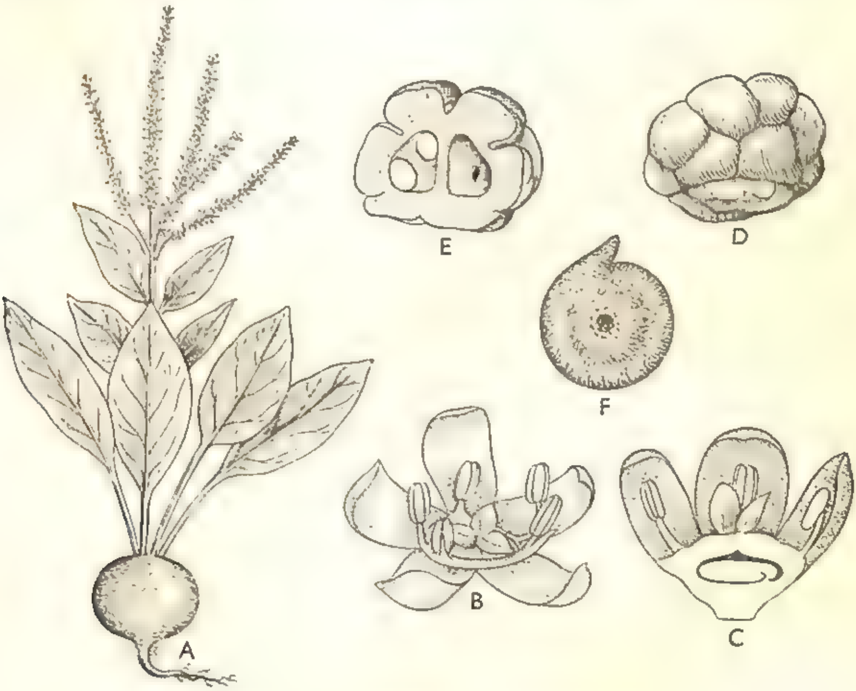


Fig. 528. Chenopodiaceae (*Beta vulgaris*).
A, An entire plant with foliage and inflorescence; B, Flower; C, V.s. of the same; D, Fruit; E, V.s. of the same; F, Seed.

(5) *Salicornia brachiata* Roxb. and (6) *Arthrocneum indicum* Moq., prostrate woody shrubs commonly found in the Sundribans. (7) Sugar beet (*Beta vulgaris* L.), commonly cultivated for obtaining sugar.

Affinity

This family is allied to Amaranthaceae in the presence of monochlamydeous flowers, uniseriate stamens and a single basal ovule in 1-celled ovary. It is also allied to Phytolaccaceae in the plan of floral structure, and is supposed that the family has been derived

from Phytolaccaceae. Chenopodiaceae is readily distinguished from allied families by the fleshy habit, absence of scarious bracts, 2-3-carpellate ovary which is 1-celled and 1-ovuled, and the nature of the embryo.

Economic importance

This family is not of much economic importance. *Spinacia oleracea*, the common spinach, is used as a vegetable. Some plants are considered to be fodder plants, such as, species of *Artiplex*, *Kochia*, etc. *Chenopodium bonus* and *Hemichroa* are cultivated as pot-herbs, and *C. quinoa* yields a sort of grain with mealy perisperm. The seeds of *C. anthelminticum* yield a kind of oil which is used as a vermifuge.

AMARANTHACEAE

General characters

Plants—mostly annual or perennial herbs, sometimes shrubs (e.g., *Deeringia*). Leaves—alternate or opposite, simple, generally

Fig. 529. Amaranthaceae (*Achyranthes aspera*).
A, Portion of a flowering shoot; B, Flower; C, The same cut lengthwise; D, Androecium; E, Pistil; F, Fruit; G, Floral diagram.

entire, often more or less hairy, exstipulate. Inflorescence—simple or compound *spike* or raceme, or dichasia. Flowers—small, regular, bisexual, sometimes unisexual (e.g., *Amaranthus*), hypogynous, with a *pair of membraneous, persistent, bracteoles.* Perianth—5, dry and *membraneous*, often *white and shining* or coloured, free or more or less united, persistent, imbricate. Stamens—5, opposite the perianth segments; filaments *often united* into a membraneous tube which may bear simple, lobed or fringed, petaloid outgrowths between two stamens. Carpels—(2-3); ovary superior, 1-celled, frequently with solitary basal or campylotropous ovule; style 1-3. Fruit—a *nutlet* or *utricle* (e.g., *Achyranthes*) or pyxis (e.g., *Celosia*). Seed—black with bony *shining testa*, and mealy endosperm. Embryo—horse-shoe shaped or annular.

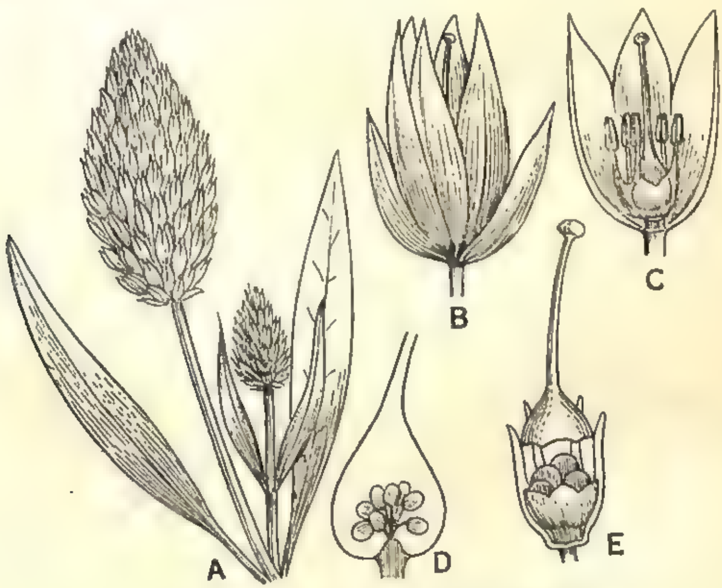


Fig. 530. Amaranthaceae (*Celosia argentea*).
A, Portion of a plant; B, Flower; C, V.s. of the same;
D, L.s. of ovary; E, Fruit dehiscing.

Number and distribution

This family consists of 64 genera and about 800 species which are chiefly found in the tropical or subtropical regions.

Key to Genera

A. Leaves usually alternate
  (*a*) Ovary 2-many-ovuled—
    Plant climbing, undershrub; fruit a berry .. *Deeringia.*

Annual herb, flowers white or pink, fruit a circumsessile capsule .. .. .. *Celosia.*

(*b*) Ovary 1-ovuled—

(*i*) Ovules erect

Flowers 1-sexual .. .. .. *Amaranthus.*

Flowers bisexual—

Fls. spicate in threes, the outer two reduced to crested scales; fruit a nut .. .. *Digera.*

Fls. capitate, fruit a circumsessile capsule .. *Allmania.*

(*ii*) Ovules suspended; fls. perfect; stamens with interposed staminodes .. .. .. *Aerua.*

B. Leaves opposite, ovary 1-celled

(*a*) Anthers 2-celled—

Flowers all perfect—

Stamens with interposed staminodes, bracts spinous *Achyranthes.*

Staminodes absent .. .. .. *Psilotrichum.*

Flowers perfect and deformed, clustered together—

Stamens with interposed staminodes .. .. *Cyathula.*

Staminodes none .. .. .. *Pupalia.*

(*b*) Anthers 1-celled—

Flowers small, white, in heads; staminal tube short; stigma capitate, subsessile .. .. *Alternanthera.*

Flowers short, white or coloured, usually capitate; staminal tube long; stigma 2-fid; style long .. *Gomphrena.*

Common plants

(1) *Amaranthus spinosa* L., a common spinous weed. (2) *Amaranthus viridis* L. and *A. gangeticus* L. are cultivated as vegetables. (3) Cocks' comb (*Celosia cristata* L.), commonly planted in gardens. (4) *Celosia argentea* L., a weed found in waste places. (5) *Achyranthes aspera* L. = *Aerva aspera* Spreng., a common weed. (6) *Alternanthera sessilis* R. Br., a very common weed found in moist places. (7) *A. pungens*, a spiny herb, common in the vicinity of salt-lakes near Calcutta. (8) *Aerua scandens* Wall. = *Aerva sanguinolenta* Bl. and *A. lanata* Juss., common weeds. (9) Globe Amaranth (*Gomphrena globosa* L.), commonly cultivated in gardens. (10) *Deeringia celosioides* Br. = *D. amaranthoids* Merr., a climbing shrub with purple berries. (11) *Pupalia atropurpurea* Moq., a common weed with hooked fruits. (12) *Digera arvensis* Forsk. = *D. muricata* Mart., a weed. (13) *Psilotrichum ferrugineum* Moq., a weed of fields and waste places. (14) *Allmania nodiflora* R. Br., a dichotomously branched annual. (15) *Cyathula prostrata* Bl., a slender erect weed.

Affinity

This family is closely allied to Chenopodiaceae but readily distinguished by the dense spicate inflorescence, scarious bracts and bracteoles, membraneous and shining perianth, and usually connate filaments.

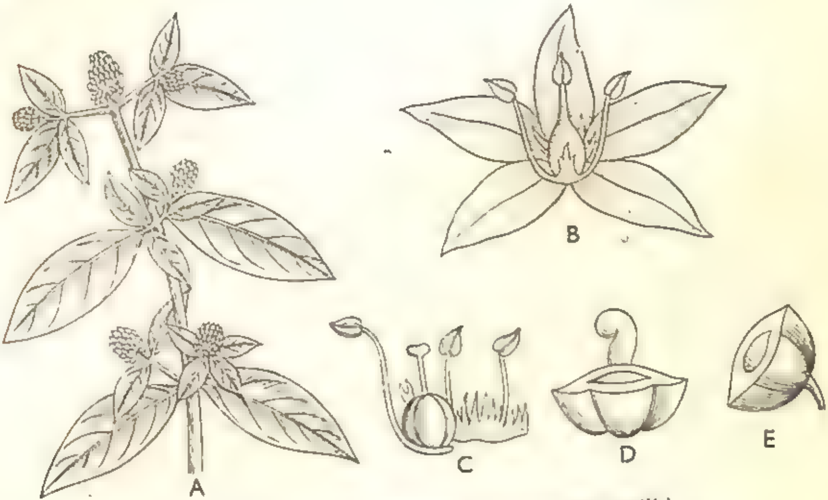


Fig. 531. Amaranthaceae (*Alternanthera sessilis*).
A, Portion of a flowering shoot; B, Flower; C, Stamen;
D, Dehiscing fruit.

Economic importance

This family is of little economic importance. Some plants are used in medicine, such as, *Achyranthes*, *Aerua*, *Amaranthus*, etc., and as pot-herbs. A few are ornamentals, such as, *Celosia*, *Gomphrena*, etc.

NYCTAGINACEAE

General characters

Plants—usually herbs or shrubs (e.g., *Mirabilis*), sometimes climbers (e.g., *Bougainvillea*, *Pisonia*). Leaves—usually opposite, simple, entire, more or less unequal, exstipulate. Inflorescence—cymose. Flowers—regular, usually bisexual (unisexual in *Pisonia*), hypogynous with involucre. Perianth—5, usually petaloid, *united* (tubular or funnel-shaped), the *lower part inflated and persistent* in fruit forming anthocarp. Stamens—5 or less. Carpel—one; ovary superior, 1-celled with *basal*, *anatropous* or *campylotropous ovule*. Fruit

—achene, enclosed in the perianth base. Seed—albuminous, with mealy perisperm. Embryo—curved or folded, with broad leaf-like cotyledons and an *inferior radicle.*

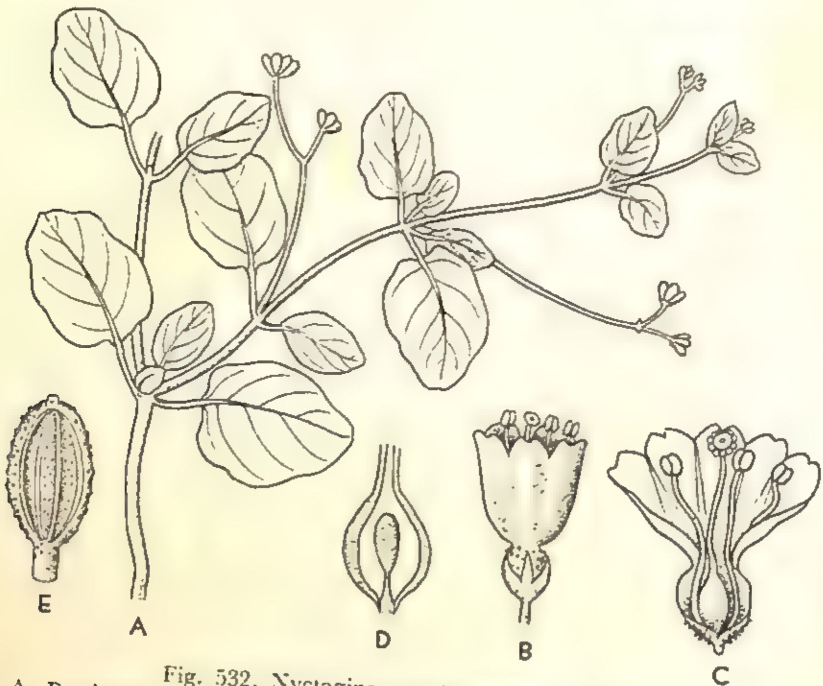


Fig. 532. Nyctaginaceae (*Boerhaavia repens*).
A, Portion of a flowering shoot; B, Flower; C, Perianth split open; D, L.s. of ovary; E, Fruit.

Number and distribution

This family consists of 28 genera and about 250 species which are found both in tropical and subtropical regions.

Key to Genera

A. Embryo hooked; radicle long; limb of perianth plicate
  (a) Leaves opposite, herbs
    (i) Flowers very small; leaves often in unequal pairs .. .. *Boerhaavia.*
    (ii) Flowers large, showy; lower leaves petioled, upper ones sessile .. .. .. *Mirabilis.*
  (b) Leaves alternate; climbing shrubs; flowers in threes, attached to midribs of large coloured bracts .. *Bougainvillea.*
B. Embryo straight; radicle short; limb of perianth induplicate-valvate; fls. small in panicled cymes .. .. *Pisonia.*

Common plants

(1) Marvel of Peru or Four o'clock plant (*Mirabilis jalapa* L.), a well-known ornamental shrub. (2) *Boerhaavia repens* L. and *B. diffusa* L. are common weeds. (3) *Bougainvillea spectabilis* Willd., a handsome climber with 3 brightly coloured bracts, often planted in gardens. (4) *Pisonia aculeata* L., a large spinous straggling shrub.

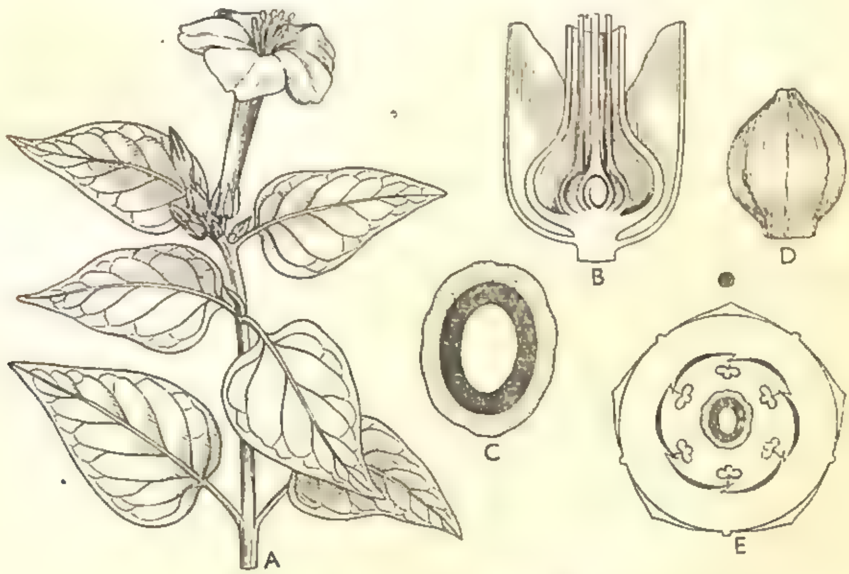


Fig. 533. Nyctaginaceae (*Mirabilis jalapa*).
A, Portion of a flowering shoot; B, V.s. of the lower portion of a flower; C, T.s. of ovary; D, Fruit; E, Floral diagram.

Affinity

This family is closely allied to Polygonaceae but readily distinguished by the sepaloid bracts, unicarpellate ovary, and the peculiar fruit enclosed in the persistent base of the perianth (anthocarp).

Economic importance

This family is of little importance economically. Some plants are used as ornamentals, such as, *Mirabilis, Bougainvillea, Abronia,* etc.

Comparison of Chenopodiaceae, Amaranthaceae and Nyctaginaceae

Chenopodiaceae	*Amaranthaceae*	*Nyctaginaceae*
1. Plants—succulent herbs or shrubs with swollen nodes.	1. Herbs or shrubs.	1. Herbs or shrubs, sometimes climbers.
2. Leaves—alternate, sometimes opposite, simple, fleshy, entire or variously lobed, sometimes scale-like, exstipulate.	2. Alternate or opposite, simple, exstipulate.	2. Opposite, simple, more or less unequal, exstipulate.
3. Inflorescence—dense spike or panicle or cymose.	3. Simple or compound spike or raceme, or dichasia.	3. Cymose.
4. Flowers—regular, bisexual sometimes unisexual, hypogynous, rarely epigynous, with scarious bracts and bracteoles.	4. Regular, bisexual sometimes unisexual, hypogynous, with scarious bracts and bracteoles.	4. Regular, bisexual rarely unisexual, hypogynous with involucre.
5. Perianth—usually 5, free or united, dry and membraneous.	5. 5, membraneous, dry and shining, persistent.	5. (5), usually petaloid, tubular or funnel-shaped, the lower part inflated and persistent.
6. Stamens—5, rarely 2, opposite the perianth leaves; filaments united at the base forming a short tube.	6. 5, opposite the perianth lobes; filaments often united at the base forming a membraneous tube.	6. 5 or less, epiphyllous.
7. Carpels—(2-3)	7. (2-3).	7. One.
8. Ovary—superior, rarely inferior, 1-celled with a campylotropous erect or pendulous ovule.	8. Superior, 1-celled with a campylotropous ovule.	8. Superior, 1-celled with a basal anatropous or campylotropous ovule.
9. Fruit—nutlet.	9. Nut or utricle or pyxis.	9. Achene.

PORTULACACEAE

General characters

Plants—usually annual or perennial herbs. Leaves—opposite or alternate, entire, *succulent*, usually stipulate (scarious stipules). Inflorescence—cymose or racemose. Flowers—regular, bisexual, hypogynous without disc. Sepals—*usually 2*, placed antero-posteriorly, imbricate. Petals—usually 4-6, free. Stamens—4-6 or more, antipetalous and united with the petals at the base. Carpels—(2-3), ovary superior (half-inferior in *Portulaca*), sunk in torus, 1-celled with 2 to many campylotropous ovules on a central basal placenta; styles and stigmas 2-5. Fruit—capsule, dehiscing circumsessilely. Seed—albuminous. Embryo—curved.

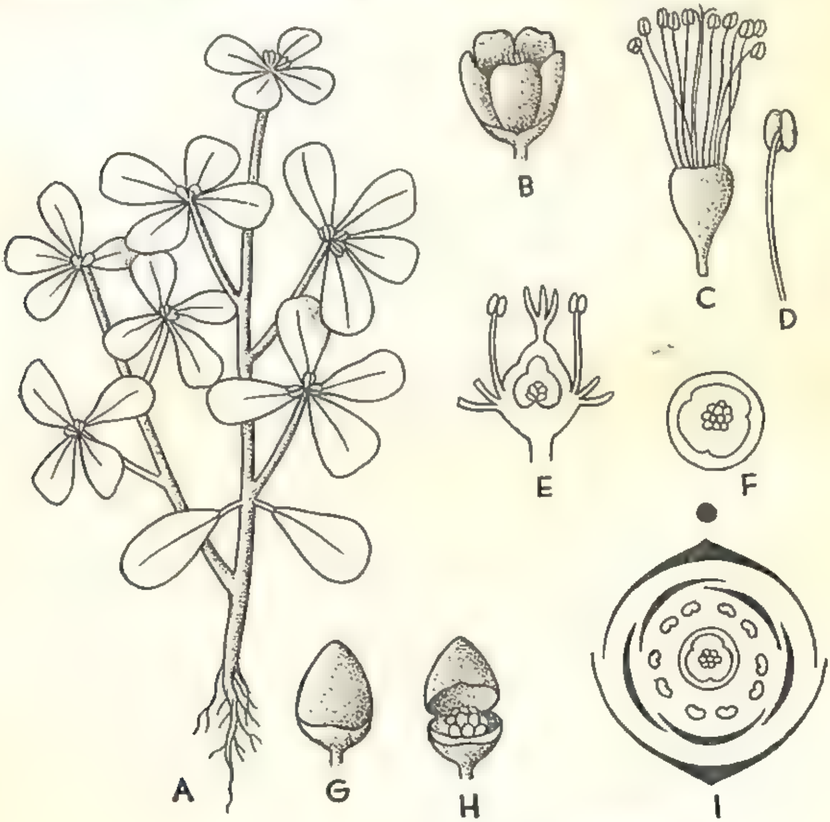


Fig. 534. Portulacaceae (*Portulaca quadrifida*).
A, An entire plant; B, Flower; C, The same with sepals and petals removed; D, Stamen; E, L.s. of ovary; F, T.s. of ovary; G, Fruit; H, Same splitting open; I, Floral diagram.

Number and distribution

This family consists of 16 genera and 500 species which are generally distributed in tropical and temperate regions.

KEY TO GENUS

Ovary half-adnate; styles 3-5-fid; fruit capsule; seeds many, reniform; fls. terminal surrounded by whorls of leaves or clustered .. .. .. *Portulaca.*

Common plants

(1) Purslane (*Portulaca oleracea* L.), (2) *P. quadrifida* L. and (3) *P. tuberosa* Roxb., are very common weeds growing in nooks and corners.

Affinity

This family is closely allied to Caryophyllaceae but readily distinguished by succulent leaves, number of sepals and stamens, and 2-5 styled 1-celled ovary with campylotropous ovules on a basal central placenta. It is also closely related to Basellaceae; the genus *Portulaca* establishes a link between them. It is also related to Aizoaceae.

Economic importance

This family is important economically from the domestic point of view. They are used as ornamentals. *Portulaca grandiflora* can be best cited as an ornamental plant. The herbage produced by *P. oleracea* is useful to certain extent as a pot herb and green salad.

BASELLACEAE

General characters

Plants—perennial *scandent herbs* with *succulent stems*. Leaves—alternate, simple, fleshy, exstipulate. Inflorescence—spike or raceme. Flowers—small, regular, incomplete, bisexual, hypogynous. Perianth—5, white or reddish, more or less united at the base, subtended by a pair of bracts forming an involucre, imbricate, *persistent*. Stamens—5, antisepalous, united with the bases of the sepals. Carpels—(3); ovary superior, 1-celled with solitary, campylotropous ovule or basal placenta; style 1; stigma usually

3-fid. Fruit—drupe, invested by the persistent perianth. Seeds—with scanty endosperm and a *rolled embryo.*

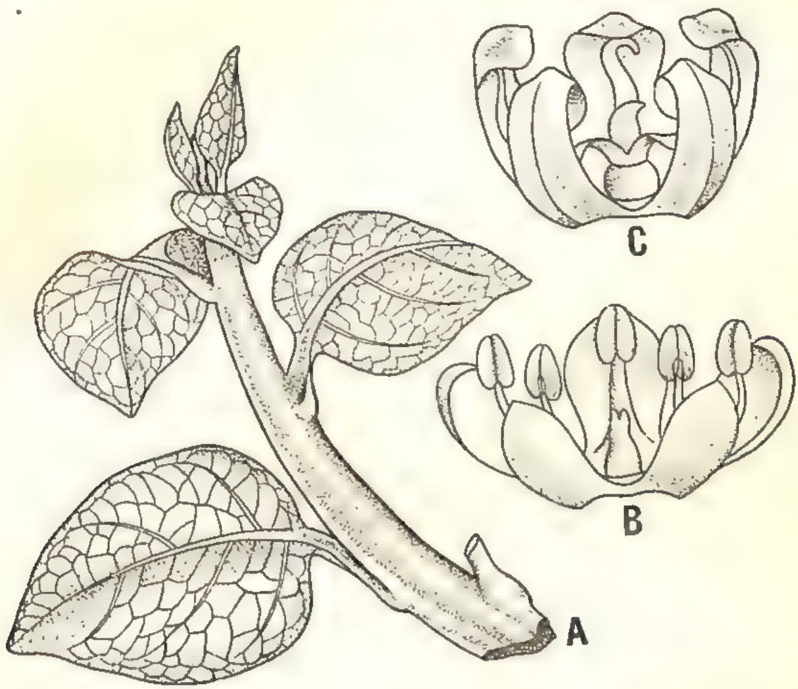


Fig. 535. Basellaceae (*Basella rubra*).
A, Portion of a shoot; B, Staminate flower; C, Pistillate flower.

Number and distribution

This family consists of 5 genera and about 22 species which are commonly found in the tropics.

Affinity

This family is readily distinguished from other members of Centrospermae by the scandent succulent character, bisexual apetalous flowers, fleshy persistent perianth leaves enveloping the fruit, and spirally twisted embryo. Bentham and Hooker included this family under Chenopodiaceae, but it differs from the latter by the biseriate perianth. It is related very closely to Portulacaceae and it is believed it arose as an offshoot of the latter.

Economic importance

This family is of little economic importance. The shoots of

Basella are taken as spinach. The tuberous roots of *Ullucus tuberosus* are eaten in America as a substitute for potato. The Madeira vine (*Boussingaultia*) is an ornamental garden plant.

CARYOPHYLLACEAE

General characters

Plants—annual or perennial herbs with swollen nodes. Leaves—*opposite*, simple, linear to lanceolate, slightly amplexicaul, usually exstipulate (excepting *Spergula*). Inflorescence—cymose (*dichasium* or *dichotomous cyme*). Flowers—regular, usually bisexual, hypogynous or perigynous. Sepals—4-5, free or united, imbricate, persistent. Petals—4-5, often clawed, free. Stamens—8 or 10, *in two whorls*, or fewer, *apparently obdiplostemonous*. Carpels—(5) often fewer with 2-5 *styles* free or united below; ovary superior, usually 1-celled with numerous ovules on the *free central placentae*. Fruit—usually a capsule, breaking into valves equal to or double the number of styles. Seeds—more or less flattened, albuminous, usually with a curved embryo (but straight in *Dianthus*).

Number and distribution

This family consists of about 80 genera and 2,100 species which are mostly found in the temperate regions of the northern hemisphere and in the mountains of the tropics.

Key to Genera

A. Calyx gamosepalous; stipules 0
- (*a*) Petals clawed; disc small or elongated into a gynophore; styles free
  - (*i*) Sepals veined; 4-valved capsule; embryo ring-like; styles 2 .. .. .. *Saponaria.*
  - (*ii*) Sepals bracteate, striated; embryo straight .. *Dianthus.*
  - (*iii*) Sepals 5-nerved; capsule 1-celled, 4-valved; embryo annular; styles 2-3 .. .. *Gypsophila.*

B. Calyx polysepalous
- (*b*) Petals sub-sessile; stamens originating from annular disc; styles free
  - (*iv*) Stipule 0; petals bifid or 0; styles 3-5; capsule globose .. .. *Stellaria.*
  - (*v*) Stipule dry and membraneous; petals entire; capsule valved .. .. .. *Spergula.*

(c) Petals subsessile; stamens on annular disc; stipule scarious; style connate

(vi) Petals 2-6-fid; sepals herbaceous .. .. *Drymaria.*

(vii) Petals entire; sepals keeled; style 3-fid .. *Polycarpon.*

(viii) Petals entire; sepals scarious; style connate; stigma 3-toothed .. .. .. *Polycarpaea.*

Range of floral structures

The flowers are typically pentamerous with formula $K_5\ C_5\ A_{5+5}\ G_{(\underline{5})}$. But deviation from the normal plan of flowers occurs either by elaboration or reduction. This family has been divided into 2 subfamilies : (a) *Alsinoideae*, where the flower is simpler or reduced type, and (b) *Silenoideae*, where the flower is highly elaborated, characterized by the tubular development of the members of the calyx.

Subfamily 1. Alsinoideae—Sepals and petals are simple in form or absent, styles free or connate. In *Spergula arvensis*, the flower is simple with white petals, 2 whorls of stamens, and 5 carpels. *Sagina* also resembles *Spergula* in floral structure but the parts are found often in 4. In *Sagina apetala* L. the petals are very much reduced or totally absent. The petals are notched in *Cerastium* and *Stellaria*. In *Stellaria* the flower is usually pentamerous, rarely tetramerous. In *Polycarpon*, the flower is reduced, the petals are sometimes absent and the stamens also are reduced in number; the styles are connate below it. In *Lyallia*, the flower is apetalous and the number of stamens is 3.

Subfamily 2. Silenoideae—The sepals are connate into a tube. The petals are found often coloured and distinguished into a claw and a limb. An outgrowth or *ligule* is found sometimes on the throat of the corolla-tube or at the junction of the claw and limb. This sort of structure (ligule) is also present in *Dianthus*, *Silene* and *Lychnis*, but it is obliterated in the genera, like *Githago* and *Gypsophila*. The flower has pentamerous arrangement with 2 whorls of stamens. The styles are free. The number of carpels is 5 in *Lychnis*, 3 in *Silene*, and 2 in *Dianthus* and *Saponaria*.

Common plants

(1) Pink (*Dianthus chinensis* L.), Carnation (*D. caryophyllus* L.) and Sweet william (*D. barbatus* L.) are common season flowers.

(2) Cow cockle (*Saponaria vaccaria* L.), a common herb. (3) Chick weed (*Stellaria media* L.), a common weed of gardens in cold weather. (4) *Polycarpon loeflingiae* Benth. & Hk. f., used as a vegetable. (5) *Gypsophila elegans* L. and Baby's breath (*G. paniculata*

Fig. 536. Caryophyllaceae (*Gypsophila elegans*).
A, Portion of a flowering shoot; B, Flower; C, Petal; D, Flower with sepals and petals removed; E, Stamen; F, T.s. of ovary; G, Floral diagram.

L.) are common season flowers. (6) *Lychnis* (maltese cross) and *Silene* (catchfly) are handsome garden plants. (7) *Spergula arvensis* L. and *Drymaria cordata* Willd. are common weeds found in Darjeeling, Shillong and other hilly places. (8) *Polycarpaea corymbosa* Lamk. is a decumbent herb found on the river banks.

Fig. 537. Caryophyllaceae (*Stellaria media*).
A, Portion of a flowering shoot; B, Flower; C, Pistil; D, T.s. of ovary; E, Floral diagram.

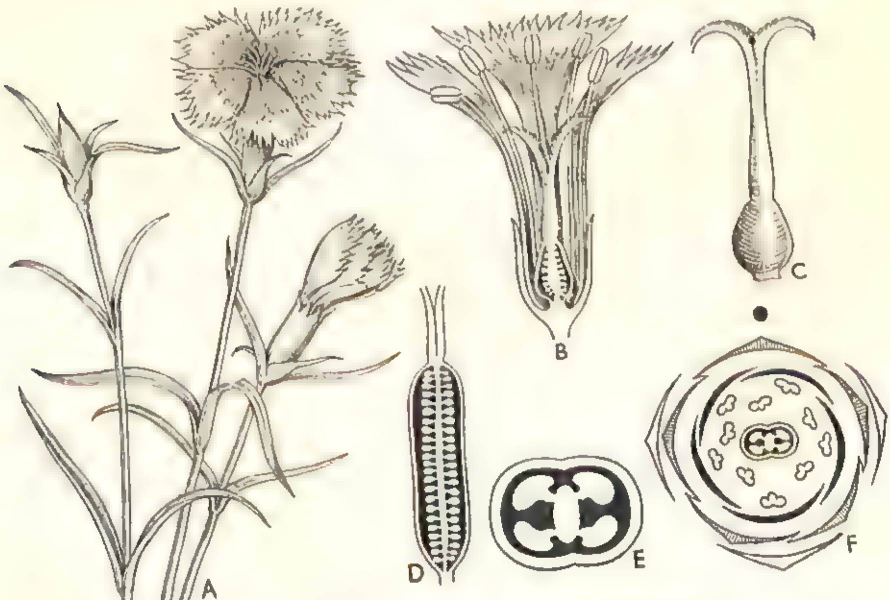


Fig. 538. Caryophyllaceae (*Dianthus chinensis*).
A, Portion of a flowering shoot; B, V.s. of a flower; C, Pistil; D, V.s. of ovary; E, T.s. of the same; F, Floral diagram.

Affinity

This family is allied to Phytolacaceae from which it has originated by conversion of the outer stamen-whorl to petals and of the outer carpel-whorl to stamens. This view was expressed by Eichler and accepted by Pax, Wettstein and Rendle. Wernham is of opinion that this family was evolved from Ranalian ancestors and Primulaceae might have arisen from Caryophyllaceae. This family is also allied to reduced families, such as Chenopodiaceae and Amaranthaceae, a view has been accepted by Bessey, Hutchinson and others. It is also related to Geraniaceae according to Dickson. This family is related to Portulacaceae but distinguished by the form of inflorescence and 2-5 free-styled flowers. It is readily distinguished from others by opposite amplexicaul leaves, 2-5-carpelled unilocular ovary with free central placentation and capsule fruit.

Economic importance

This family is of some economic importance. A large number of plants are useful for ornamental purposes, such as *Gypsophila*, *Silene*, *Lychnis*, *Cerastium*, *Dianthus*, etc. Some plants are used as fodder, such as, *Spergula arvensis*. The roots of *Saponaria* produce 'saponin' which gives lather when rubbed with water. *Polycarpon* and *Gypsophila* are used as vegetables.

ORDER 18. RANALES

Flowers hypogynous to epigynous, acyclic to cyclic (in advanced members), regular, rarely zygomorphic. Thalamus elongated, convex, sometimes concave. Perianth differentiated into calyx and corolla or similar, petaloid. Stamens usually numerous. Carpels many to one, often free. Seeds with copious endosperm, sometimes with perisperm.

Engler has placed this Order in the 18th position under subclass Archichlamydeae containing 18 families, *viz.*, Nymphaeaceae, Ranunculaceae, Magnoliaceae, Anonaceae, etc. In Bentham and Hooker's system this Order is designated as cohort Ranales which consists of families Ranunculaceae, Magnoliaceae, Anonaceae, Nymphaeaceae, etc. Hutchinson has divided this Order into two distinct parts, keeping Ranales for the herbaceous plants, while making a new Order Magnoliales for the arborescent types. This

Order (4th Order) consists of 4 families, *viz.*, Ranunculaceae, Nymphaeaceae, etc. Magnoliaceae has been put under the Order Magnoliales (1st Order) and Anonaceae in the Order Anonales (2nd Order).

NYMPHAEACEAE

General characters

Plants—annual (e.g., *Euryale*) or perennial *aquatic herbs* with cauline (e.g., *Cabomba*) or rhizomatous stems embedded in the mud. Leaves—often floating (submerged in *Nelumbium*), peltate or cordate, on long petioles (but sessile in *Cabomba*). Flowers—solitary, usually on a scape, large and showy, regular, bisexual, hypogynous to epigynous (e.g., *Euryale*), acyclic, hemicyclic, or cyclic. Sepals —3-6, free or adnate to the torus. Petals—3 (e.g., *Cabomba*) to numerous, *often gradually passing into stamens*, imbricate. Stamens—3-6 (e.g., *Cabomba*) or numerous; filaments foliaceous. Carpels—8 or more, united into a many-celled ovary (e.g., *Nymphaea* and *Nuphar*) or free and sunk in spongy thalamus (e.g., *Nelumbium*); ovary superior or inferior (e.g., *Victoria* and *Euryale*); ovules 1 to many on the inner walls or from the apex of the carpels. Fruit—a follicle (e.g., *Cabomba*), or aggregate of achenes (e.g., *Nelumbium*) or spongy berry (e.g., *Euryale*). Seeds—often arillate, generally with both perisperm and endosperm, and a straight embryo.

Number and distribution

This family consists of 8 genera and about 90 species which are cosmopolitan.

KEY TO GENERA

A. Carpels embedded irregularly in the pits of obscure thalamus
  (*a*) Sepals 4-5; petals and stamens numerous; seeds exalbuminous .. .. *Nelumbium.*
B. Carpels confluent with one another or with the ovary
  (*b*) Sepals, petals and stamens half-inferior, inserted on a disc, confluent with the carpels .. .. *Nymphaea.*
  (*c*) Sepals, petals and stamens inferior; ft. a prickly berry .. .. *Euryale.*

Range of floral structures

The chief constant floral characters of the family are spirocyclic,

regular, bisexual flowers or rarely cyclic with gradual change from sepals to petals and to stamens.

This family has got wide variation in the construction of floral parts. The variation occurs mainly due to number of sepals and petals, nature of thalamus, apocarpy or syncarpy.

This family has been subdivided into 3 tribes based on the floral range and construction of floral parts.

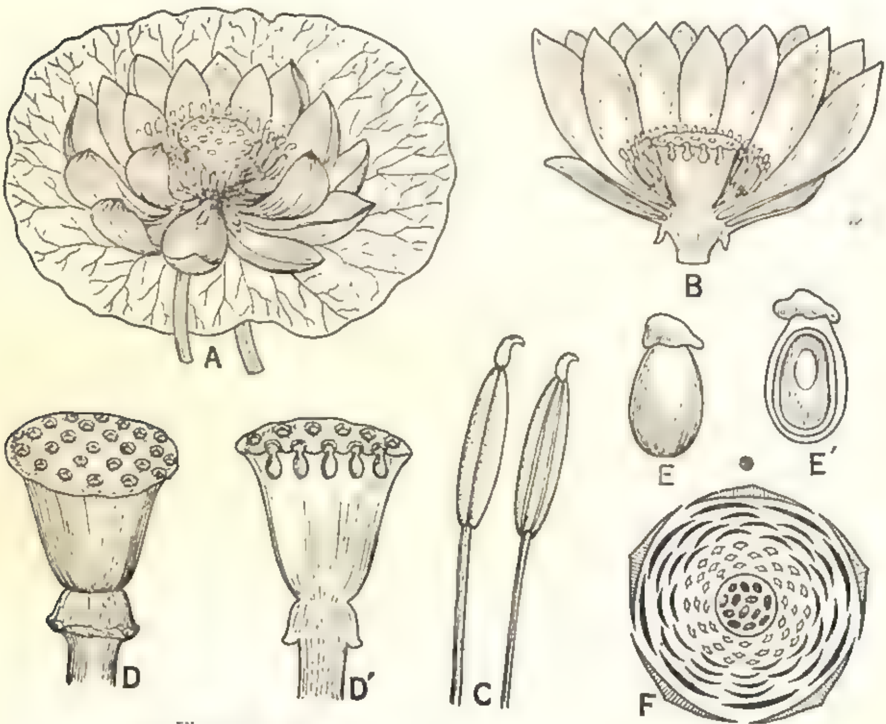


Fig. 539. Nymphaeaceae (*Nelumbium speciosum*).
A, A flower with a leaf on the background; B, L.s. of a flower; C, Stamens; D, Thalamus; D′, L.s. of the same; E, Seed; E′, L.s. of the same; F, Floral diagram.

Tribe 1. Caboomboideae

The tribe is represented by the genus *Cabomba*, which consists of 6 perianth leaves in two whorls (3+3), the outer one forms the calyx and the inner one petals. Stamens 6. Carpels 3, free. Flowers are cyclic, trimerous and hypogynous.

Tribe 2. Nelumboideae

The tribe is represented by the only genus, *Nelumbo*, which con-

sists of indefinite perianth leaves, the outer whorl of 5 sepals; carpels numerous but spirally arranged. Stamens indefinite; carpels free. Flowers are acyclic and hypogynous.

Tribe 3. Nymphaeoideae

This tribe is represented by the most prominent genus *Nymphaea*. It consists of 4-5 sepals in whorls and indefinite petals; stamens indefinite; carpels numerous, fused. Flowers are hypo-, peri-, or epigynous (e.g., *Euryale*).

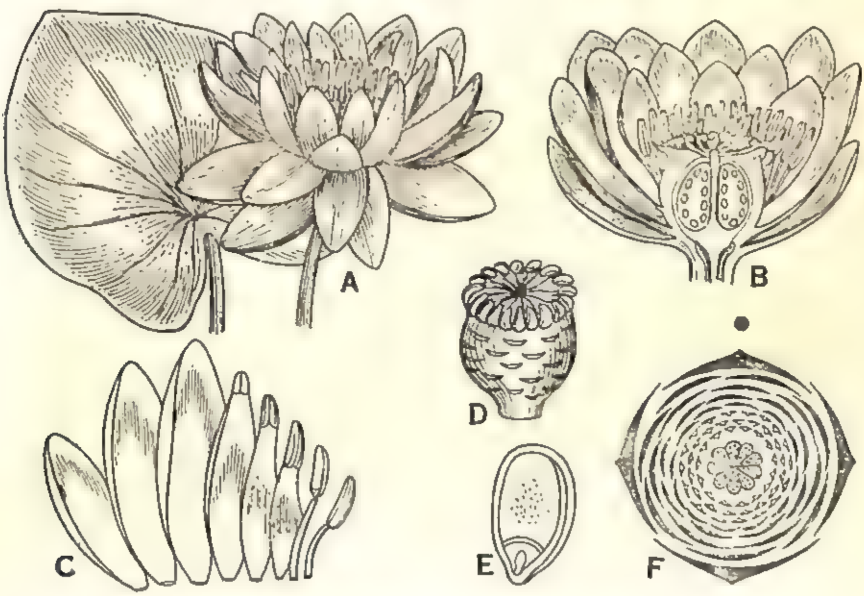


Fig. 540. Nymphaeaceae (*Nymphaea lotus*).
A, A flower with a leaf on the background; B, L.s. of a flower; C, Transition of petals into stamens; D, Pistil; E, L.s. of a seed; F, Floral diagram.

Common plants

(1) Water-lily or Pond-lily (*Nymphaea lotus* L., *Nymphaea pubescens* Willd).. (2) Red water-lily (*Nymphaea rubra* Roxb.). (3) Blue water-lily (*Nymphaea stellata* Willd.). (4) Lotus (*Nelumbium speciosum* Willd. =*Nelumbo nucifera* Gaertn.). (5) *Euryale ferox* Salisb., commonly found in the tanks of Eastern Pakistan, all parts of which are beset with prickles. (6) Yellow water-lily (*Nuphar luteum* L.). (7) *Cabomba aquatica*, commonly cultivated in the aquarium.

Affinity

This family bears relationship with Papaveraceae in the character of superficial placentation of the ovary and large peltate-rayed stigmas. It is allied to Magnoliaceae in the character of accessory whorls and stamens. It also establishes a close link with Alismataceae in the structure of the ovary. Nymphaeaceae is readily distinguished by the aquatic habit, usually long-petioled peltate leaves and long-peduncled flowers, and parietal or superficial placentation.

Fig. 541. Nymphaeaceae (*Cabomba aquatica*).
A, Portion of a flowering shoot; B, Fruit; C, Floral diagram.

Economic importance

This family has very little economic importance. Fruits and rhizomes of many species are edible. Most plants are cultivated as ornamentals.

RANUNCULACEAE

General characters

Plants—generally annual or perennial herbs (trees in *Paeonia*), sometimes woody and climbing (e.g., *Clematis* and *Naravelia*).

Leaves—radical or cauline, alternate, rarely opposite (e.g., *Clematis* and *Naravelia*), simple (sometimes compound, e.g., *Caltha*), shape varies from entire to decompound (e.g., *Thalictrum*), *with sheathing leaf bases*, exstipulate. Inflorescence—cymose, sometimes racemose (e.g., *Delphinium*, *Aconitum*, etc.). Flowers—generally bisexual (unisexual in *Thalictrum*), acyclic or hemicyclic, mostly regular (irregular in *Delphinium* and *Aconitum*), hypogynous. Perianth—simple and petaloid, generally succeeded by various forms of nectaries (*honey leaves*), or differentiated into distinct calyx and corolla, imbricate; sepals 5 or more, deciduous, often petaloid; petals 5 or more. Stamens—*numerous*, *spirally arranged*, free with extrorse anthers. Carpels—usually *numerous*, rarely reduced to one; free or partly united (e.g., *Nigella*); ovary superior, 1-celled with numerous to few ovules on the ventral suture. Fruit—usually an etaerio of many-seeded follicles or 1-seeded achenes with long persistent styles (e.g., *Clematis*, *Naravelia*), or berry (e.g., *Actaea*). Seeds—with copious oily endosperm and a small embryo.

Number and distribution

This family contains about 35 genera and 1,500 species which are usually found in the temperate and colder parts of the globe.

KEY TO GENERA

A. Carpels 1-ovuled; fruit achenes.
- (*a*) Leaves opposite, compound; plants usually climbing
  - (*i*) Sepals 4, petaloid; petals 0; no tendril .. *Clematis*.
  - (*ii*) Sepals as many as petals, 4 or 5; third or terminal leaflet modified into tendril .. .. *Naravelia*.
- (*b*) Leaves alternate or radical; plants usually herbs
  - (*iii*) Sepals petaloid; petals 0; fls. involucrate .. *Anemone*.
  - (*iv*) Sepals petaloid; petals 0; fls. non-involucrate .. *Thalictrum*.
  - (*v*) Sepals 3-5, deciduous; petals 5 .. .. *Ranunculus*.

B. Carpels many-ovuled; fruit follicles
- (*c*) Leaves alternate or radical; plants usually herbs
  - (1) Carpels united at the base; fls. regular
    - (*vi*) Sepals petaloid and as many as petals; 5 petals long, clawed and bifid; leaves bipinnate .. .. .. *Nigella*.
  - (2) Carpels free; fls. irregular
    - (*vii*) Sepals 5, yellow or white, posterior one helmet-shaped; leaves palmatipartite or seldom entire; plants usually twining .. *Aconitum*.

(*viii*) Sepals 5, pale blue or purplish, dorsal members spurred like those of petals; leaves palmately lobed; plants erect .. *Delphinium.*

Range of floral structures

The family Ranunculaceae has wide range of variation in the floral construction. The members of the family generally consist of regular flowers but zygomorphic flowers are often noted, as in

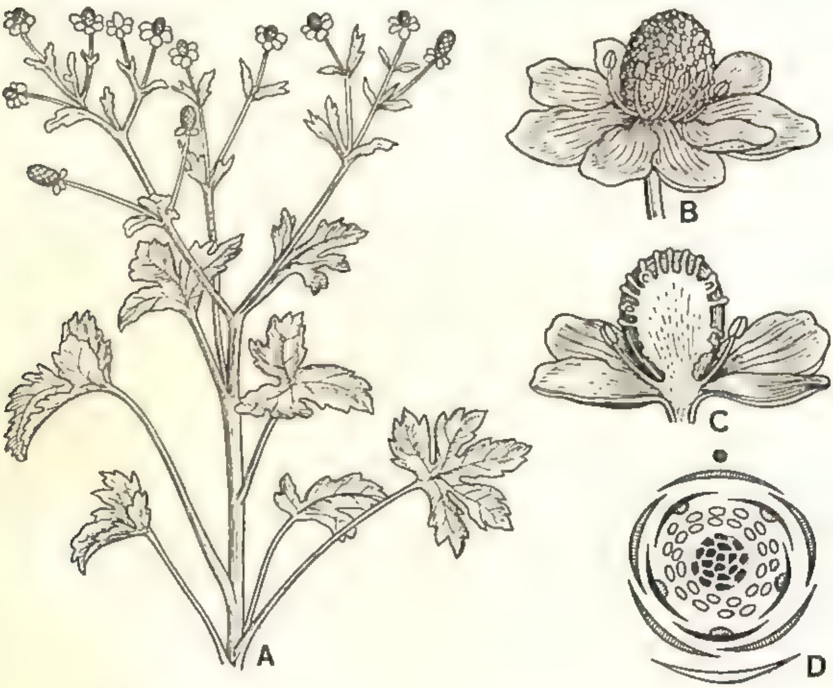


Fig. 542. Ranunculaceae (*Ranunculus sceleratus*).
A, Portion of a flowering shoot; B Flower; C. Vertical section of the same; D, Floral diagram.

Aconitum and *Delphinium.* In *Caltha* and *Paeonia*, the flowers are acyclic or hemicyclic. There is also found a gradual transition from sepals to petals as in *Nymphaea* of Nymphaeaceae. In *Caltha*, number of perianth leaves being 5-15, deciduous; stamens are very numerous in many rows ; carpels 5-10.

Typical pentamerous flowers are very rare and it is only seen in specimens *Xanthorrhiza* and *Aquilegia.* In *Nigella* the perianth leaves are generally five which are petaloid—true petals absent, honey leaves present and they are 8 in number. Stamens

numerous, arranged in 8 rows; carpels 5, connate in a 5-celled syncarpous pistil.

Prantl classified the family into *three* tribes according to the construction of flowers :

I. Paeoniodeae : Ovules in two rows, longitudinally disposed on the ventral suture of the carpel. Perianth double, the outer perianth calyx-like but sometimes petaloid to some extent. Honey leaves are absent. Examples: *Paeonia* and *Caltha*.

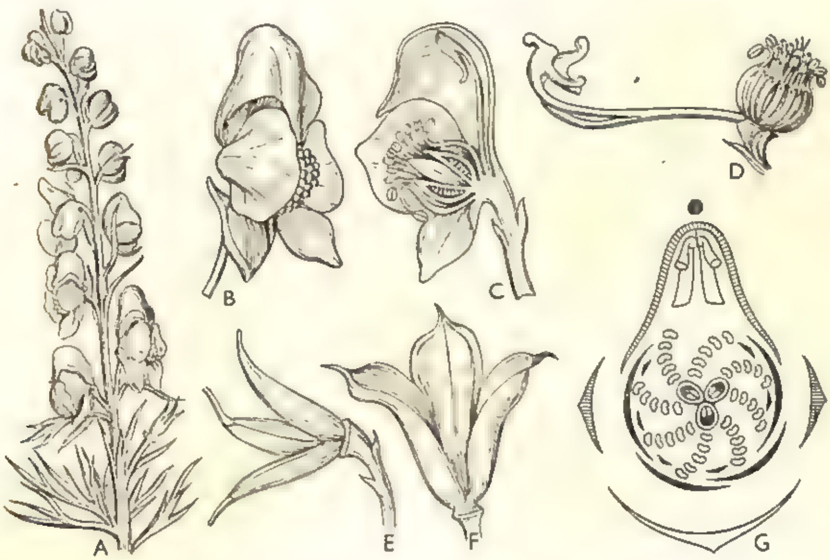


Fig. 543. Ranunculaceae (*Aconitum napellus*).
A, Portion of a flowering shoot; B, Flower; C, V.s. of the same; D, The same after removal of calyx and corolla; E, Pistil; F, Fruit; G, Floral diagram.

II. Helleboroideae : Ovules in two rows, rarely 1 or 2, longitudinally disposed on ventral suture. Honey leaves present. Perianth double due to formation of honey leaves, inner half of the perianth petaloid, rarely sepaloid, honey leaves small generally.

(a) Perianth petaloid and the honey leaves are tongue-shaped, as found in *Helleborus*.

(b) Perianth sepaloid and honey leaves are petaloid, as found in *Aquilegia*.

III. Anemonoideae : Ovules solitary, mostly basal. Carpels numerous; perianth is double or single or it consists of 2 or more

whorls, petaloid or sepaloid. Examples: *Anemone*, *Naravelia*, *Clematis*, etc.

Common plants

(1) *Naravelia zeylanica* DC., a common wild climbing plant with ternate leaves, the terminal leaflet of which is converted into a tendril. (2) Virgin's bower (*Clematis gouriana* Roxb.), a climbing plant with opposite pinnate leaves which climb up by twisting the petiole. (3) Indian Buttercup (*Ranunculus sceleratus* L.), an erect

Fig. 544. Ranunculaceae (*Clematis gouriana*).
A, Portion of a flowering shoot; B, Flower; C, Stamen; D, Carpel; E, L.s. of ovary; F, Floral diagram.

herb, generally found on the banks of rivers and marshes. (4) Larkspur (*Delphinium ajacis* L.), a commonly cultivated garden annual. (5) Fennel flower or Black cumin (*Nigella sativa* L.), cultivated for its seeds which are largely used as a condiment and also as a preservative of clothes against the attacks of vermins. (6) Monkshood (*Aconitum napellus* L.), a commonly cultivated garden annual. (7) *Anemone pulsatilla* and (8) *Delphinium staphysagria* are medicinal plants. (9) Meadow rue (*Thalictrum javanicum* Bl.), a slender herb with decompound leaves, chiefly found on the hills.

Affinity

The structure of the essential organs relates the family closely to Magnoliaceae, which is readily distinguished by having distinct stipules and different habit. The dimorphic leaves, small flowers with free, hypogynous parts and fruit of *Cabomba* establish a close link with that of the genus *Ranunculus*. It resembles the family

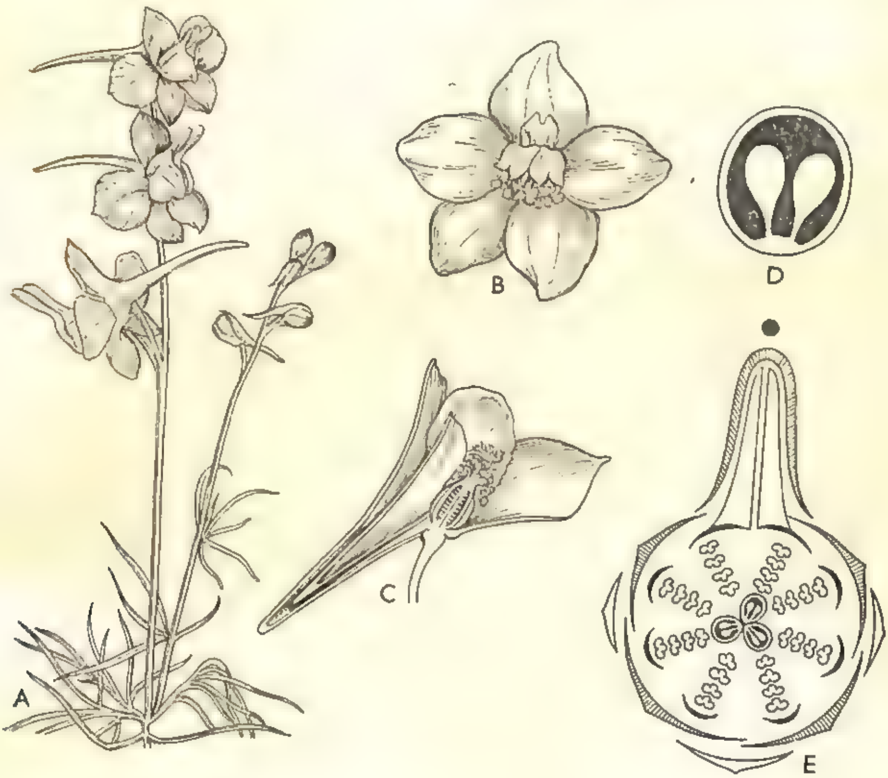


Fig. 545. Ranunculaceae (*Delphinium ajacis*).
A, Portion of a flowering shoot; B, Flower; C, V.s. of the same; D, T.s. of ovary; E, Floral diagram.

Papaveraceae but it is distinguished by having distinct carpels. It is also readily distinguished from Rosaceae by its hypogynous stamens, abundant perisperm and general properties. The most remarkable feature in the family lies in its close link with the monocotyledons. The presence of tubular cotylar sheath and union of two cotyledons in *Ranunculus ficaria*, indicate a probable affinity with the monocotyledons. The presence of free carpels and general

habit of Alismataceae with Ranunculaceae, have established a close relationship. Ranunculaceae is distinguished from allied families by the usually herbaceous habit, the leaves often divided or compound, the flowers mostly bisexual with reduced or modified petals, the stamens usually numerous and spirally arranged, the gynoecium of generally several to many pistils, and the ovary unicarpellate. The genus *Actea* with its solitary carpel forms a link with Berberidaceae.

Economic importance

This family is best regarded as ornamental plants (e.g., *Anemone*, *Delphinium*, *Clematis*, *Aquilegia*, *Helleborus*, *Thalictrum*, *Paeonia*, etc.). Many of the species (*Anemone pulsatilla*, *Delphinium staphysagria* L., *Aconitum napellus* L., *Cimicifuga racemosa* Nutt., *Hydrastis canadens* L.) are useful in medicine. Cumin seeds are largely used as a condiment and also as a preservative of clothes against the attacks of vermins.

MAGNOLIACEAE

General characters

Plants—shrubs or trees. Leaves—alternate, simple, coriaceous, entire, stipulate. Flowers—solitary, terminal or axillary, usually bisexual (rarely unisexual, e.g., *Drimys*, *Schizandra*), regular, hypogynous, acyclic, *trimerous;* thalamus convex or elongated. Perianth—consists of 9 or more free petaloid parts, or the 3 outer ones green, arranged in whorls, hypogynous, *imbricate.* Stamens—usually *numerous*, *free*, spirally arranged on the lower portion of the floral axis (androphore). Carpels—numerous, free, spirally arranged on an elongated conical floral axis (gynophore), ripe carpels dehiscent; ovary superior, 1-celled; ovules 2 to many, anatropous on the ventral suture. Fruit—*aggregate* (follicle) or berry. Seeds—pendulous, suspended for a time by slender threads, one or few, with a copious endosperm and a small embryo.

Number and distribution

This family consists of 10 genera and over 100 species, which are found mostly in the tropics but a few may be found in the temperate zone.

KEY TO GENERA

Erect trees or shrubs; conspicuous.

(a) Gynophore absent

Carpels closely aggregated; ft. dehiscing dorsally; ovules 2 or few; fls. terminal .. .. *Magnolia.*

(b) Gynophore present

Carpels in loose spike; gynophore stalked, persistent: fls. axillary, solitary .. .. .. *Michelia.*

(terminal in *M. cathcartii* Hk. f. & T. = *Alcimandra cathcartii* Dandy, reported from the temperate forest of Sikkim Himalayas)

Fig. 546. Magnoliaceae (*Michelia champaca*).
A, Portion of a flowering shoot; B. Flower; C, The same after removal of petals; D, Stamen: E, Pistil; F, Carpel; G, Aggregate fruit; H, Fruit split open.

Common plants

(1) The Champak (*Michelia champaca* L.), (2) *Magnolia pterocarpa* Roxb., (3) *Magnolia grandiflora* L., all of which produce fragrant flowers and for this reason are cultivated in the gardens. (4) *Magnolia campbellii*, a shrub producing beautiful flowers can be found in Darjeeling.

Affinity

This family is considered to be as most primitive among the dicotyledons. The primitive character is exemplified by spiral arrangement of stamens and carpels, and apocarpous pistil. It also establishes a close link with gymnosperms. The gymnospermous character of wood, *i.e.*, tracheids with bordered pits, has been revealed in the genus *Drimys*. It has been presumed by some authors that the elongated floral axis of a *Magnolia*, which bears numerous spirally arranged free sporophylls indicate a probable relationship with *Bennettites*, a genus of Bennettitales, particularly in the presence of sporophyll-bearing axis of the same. Magnoliaceae is also allied to Anonaceae from which it is readily distinguished by having imbricate corolla and uniform albumen. The family is characterized by the bisexual flowers, numerous stamens and carpels spirally arranged on an elongated floral axis (torus).

Economic importance

Economically, the family is not very much important with the exception of the flowers of many species of *Magnolia* and *Michelia*, as they are handsome, showy and fragrant. The Tulip tree (*Liriodendron tulipifera*) is sometimes grown as an ornamental plant. The species of *Drimys*, particularly its bark known as Winter's bark, is used in medicine. The fruit of *Illicium verum* Hook. f. is sometimes used for medicinal purpose. The wood of *Liriodendron*, *Michelia excelsa* and several species of *Magnolia* is used in making furniture and cabinet work.

ANONACEAE

General characters

Plants—trees or shrubs, sometimes climbers (e.g., *Artabotrys*). Leaves—alternate, simple, entire, *gland-dotted*, exstipulate. Flowers—regular, usually bisexual, hypogynous, solitary, *trimerous*. Sepals—3, small, usually free or united below, *valvate*. Petals—6 (in two series) or 3 (e.g., *Anona*), *valvate* or imbricate (e.g., *Uvaria*). Stamens—numerous, spirally set on a convex thalamus; filaments short and thick; anthers linear with *prolonged truncate connective*, extrorse. Carpels—usually numerous, free and spirally set on the thalamus, ripe carpels indehiscent; ovary superior, 1-celled; ovules usually numerous in a double row on the ventral suture of the carpel; style

short or absent. Fruit—an *etaerio of drupes*, but in *Anona* the ripe carpels are fused together forming a large fleshy fruit (*composite berry*). Seed—often arillate with *ruminated albumen* and a minute embryo.

Number and distribution

This family consists of about 80 genera and 850 species which are widely spread in the tropics.

KEY TO GENERA

A. Carpels numerous, distinct, indehiscent.
- (*a*) Petals imbricate in bud
  - (*i*) Corolla-members biseriate; sepals valvate; connective truncate; torus flat .. .. *Uvaria.*
- (*b*) Petals valvate in bud
  - (*ii*) Corolla-members conniving at the concave base covering the stamens with truncated or produced anther-cells; peduncles hooked .. .. *Artabotrys.*
  - (*iii*) Corolla members spreading from the base, flat, lanceolate; anther-cells lanceolate
    - (1) Ovules numerous in 2 series on the ventral suture .. .. .. *Cananga.*
    - (2) Ovules 2-6, uniseriate on the ventral suture *Unona.*
    - (3) Ovules 1-2, basal or subbasal; stamens cuneate; ft. 1-seeded .. .. *Polyalthia.*

B. Carpels numerous, united into a fleshy fruit
- (*c*) Petals 3-6 in 2 series, valvate in bud; stamens numerous; ovaries numerous, partially united: ovule 1, erect .. .. *Anona.*

Common plants

(1) Custard apple (*Anona squamosa* L.). (2) Bullock's heart (*Anona reticulata* L.). (3) *Polyalthia longifolia* Benth. & Hook. f., an ornamental tree whose foliage is largely used for decorative purpose on festive occasions. (4) *Polyalthia cerasoides* Benth. & Hook., a tree commonly found in the thickets. (5) *Artabotrys odoratissimus* R. Br. = *A. uncinatus* Merr., a hook climber which is usually cultivated in gardens for its fragrant flowers. (6) *Uvaria macrophylla* Roxb. = *Fissitigma macrophylla* Merr., a woody climber found in Eastern Pakistan. (7) *Cananga odorata* Hook. & Thoms. = *Desmos chinensis* Lour., a small tree often planted in gardens.

Affinity

This family shows an affinity with Magnoliaceae but ruminate endosperm, valvate corolla, prolonged connective, and exstipulate leaves separate it from the latter. The trimerous flower and small embryo establish a close relationship with monocotyledons.

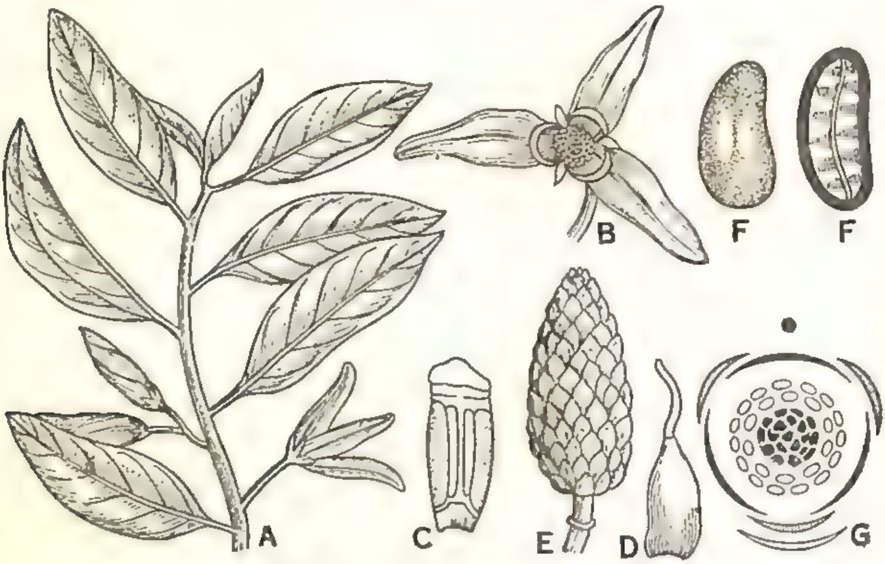


Fig. 547. Anonaceae (*Anona squamosa*).
A, Portion of a flowering shoot; B, Flower; C, Stamen; D, Pistil; E, Fruit; F, Seed and L.s. of the same; G, Floral diagram.

Economic importance

This family is of some economic importance. *Anona squamosa* and *A. reticulata* yield sweet and fleshy edible fruits. Species of *Polyalthia* are grown as ornamental trees; its wood is used for making masts.

Comparison between Magnoliaceae and Anonaceae

Magnoliaceae	*Anonaceae*
1. Leaves—coriaceous, stipulate.	1. gland-dotted, exstipulate.
2. Flowers—large, showy.	2. small.
3. Sepals petaloid.	3. petals sepaloid.
4. Petals—6-many, imbricate.	4. never more than 6, valvate.
5. Anthers—generally introrse.	5. extrorse, linear with prolonged connective.
6. Fruit—etaerio of follicles or drupes.	6. etaerio of drupes or a composite berry.
7. Albumen—uniform.	7. ruminated.

LAURACEAE

General characters

Plants—trees or shrubs (excepting *Cassytha*, a twining parasitic perennial herb), *with aromatic bark and foliage*. Leaves—usually alternate, simple, entire, coriaceous, mostly curviveined (but in *Cassytha* reduced to scales or absent), exstipulate. Inflorescence—raceme, spike, umbel or panicle. Flowers—small, greenish or yellowish, regular, bisexual (sometimes unisexual), hypogynous, trimerous. Perianth 3+3, more or less united at the base, *sepaloid*, *persistent*, imbricate. Stamens—12, *usually in 4 whorls of 3 stamens* each, generally the innermost is reduced to a whorl of staminodes (e.g., *Cinnamomum*), the third whorl usually bears a pair of glandular protuberances, inserted to the perianth tube; *anthers*

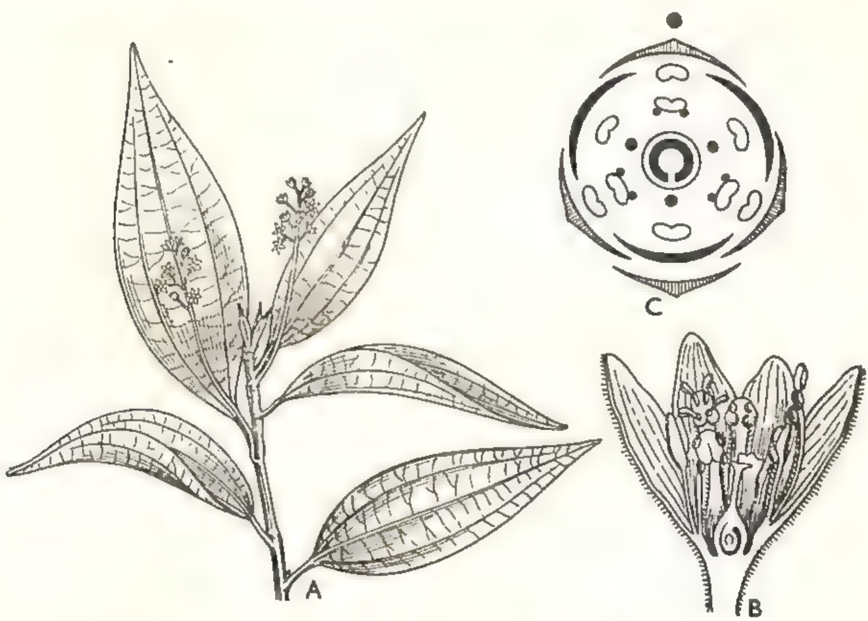


Fig. 548. Lauraceae (*Cinnamomum zeylanicum*).
A, Portion of a flowering shoot; B, V.s. of a flower; C, Floral diagram.

usually with valvular dehiscence. Carpel—1; ovary superior, 1-celled with 1 anatropous pendulous ovule, placentation marginal. Fruit—*drupe*, sometimes berry and more or less enveloped by the cup-shaped receptacle, and sometimes also by the persistent base of the perianth (e.g., *Cassytha*). Seed—*exalbuminous with large straight embryo*.

Number and distribution

This family contains about 45 genera with 1,100 species, distributed in the tropical and subtropical regions.

Key to Genera

A. Shrubs or trees
 (a) Anthers 2-celled
  (i) Perianth tube persistent, lobes 6, subequal .. *Cryptocarya.*
  (ii) Perianth tube deciduous, perianth lobes 5, subequal, staminodes ovate or cordate .. *Beilschmiedia.*
  (iii) Perianth tube deciduous, perianth lobes 6, staminodes minute or absent .. .. *Dehaasia.*
 (b) Anthers 4-celled
  (iv) Perianth in fruit with deciduous lobes, persistent, wholly or partly .. .. .. *Cinnamomum.*
  (v) Perianth in fruit persistent; leaves alternate
   Lobes of perianth reflexed in fruit .. .. *Machilus.*
   Lobes of perianth erect in fruit .. .. *Phoebe.*
B. Parasitic, leafless twining herbs .. .. .. *Cassytha.*

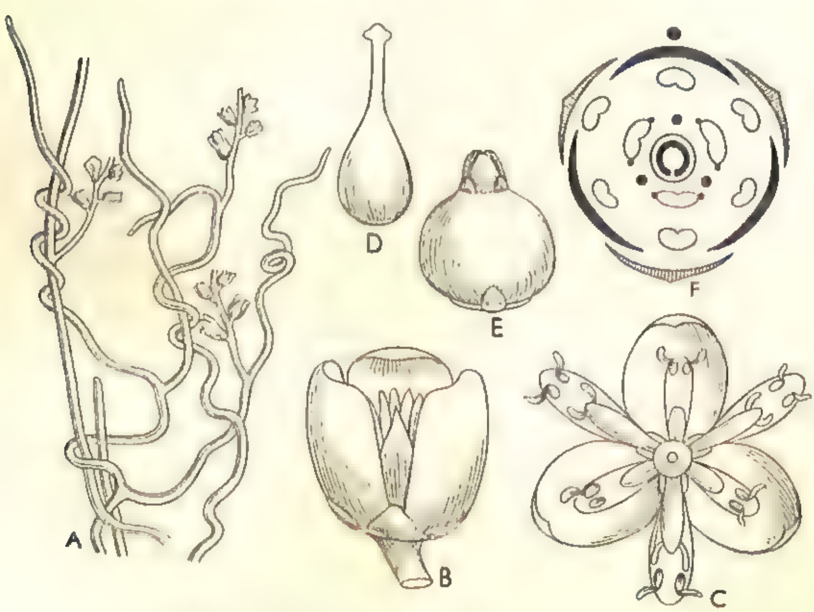


Fig. 549. Lauraceae (*Cassytha filiformis*).
A, Portion of a plant; B, A flower bud; C, A flower; D, Pistil; E, Fruit; F, Floral diagram.

Common plants

(1) *Cryptocarya floribunda* Nees., a tree. (2) *Beilschmiedia roxburghiana* Nees., a deciduous tree. (3) Camphor tree (*Cinnamomum camphora* Nees.), yields camphor. (4) *C. tamala* Nees., a medium tree, the leaves of which are used as a spice in cooking. (5) Cinnamon (*C. Zeylanicum* Breyn.), a small tree, the bark of which is used as a spice. (6) *Cassytha filiformis*, a common leafless thread-like greenish parasite. (7) *Dehassia kurzi* King, an evergreen tree, commonly found in E. Pakistan. (8) *Machilus vilosa* Hook. f., a large tree. (9) *Phoebe lanceolata* Nees., an evergreen tree.

Affinity

This family is readily distinguished from allied families by the presence of small undifferentiated perianth, trimerous stamens in several whorls, valvular dehiscence of anthers, drupe-like fruit and single exalbuminous seed with large straight embryo.

Economic importance

The family is economically important. Many plants yield aromatic oils. Camphor is obtained from *Cinnamomum camphora; C. tamala* and *C. zeylanica* yield spices. Some plants of this family, viz., *Persea*, *Sassafras*, etc. yield fragrant wood for cabinet work. A few species are ornamental.

ORDER 19. RHOEDALES

Plants usually herbs. Flowers hypogynous, regular, cyclic with perianth members usually 4 in number, rarely 3. Carpels two or more, united. Placentation parietal. Seeds usually small with curved embryo.

According to Engler the Order consists of 4 suborders containing 6 families, *viz.*, Papaveraceae, Capparidaceae, Cruciferae, etc. Bentham and Hooker have placed the aforesaid families in the cohort Parietales under the subclass Polypetalae. In Hutchinson's system this Order (8th Order) consists of 2 families only, *viz.*, Papaveraceae and Fumariaceae. Capparidaceae has been placed in the 10th Order Capparidales and Cruciferae in the 11th Order Cruciferales.

PAPAVERACEAE

General characters

Plants—generally annual herbs (shrubs in *Dendromecon*) with milky or coloured *latex*. Leaves—alternate, simple, entire or more often lobed or much divided, exstipulate. Flowers—solitary, terminal or axillary, bisexual, regular, hypogynous. Sepals—2 (sometimes 3), free, caducous, imbricate. Petals—usually 2+2 (sometimes 3+3), absent in *Macleaya*, *crumpled*, deciduous. Stamens—numerous, in *several alternating whorls* (generally multiple of 2 or 3); anther bilocular. Carpels—two or more, syncarpous; ovary superior 1-celled, with numerous anatropous or campylotropous ovules on *parietal placentae*, (but basal placentation in *Bocconia*) or many-celled; stigma radiating from the centre, either sessile or supported on a distinct style. Fruit—capsule, opening by apical pores or valves. Seeds—with oily endosperm and a minute embryo.

Number and distribution

This family consists of 28 genera and about 250 species which are usually found in the North temperate zones.

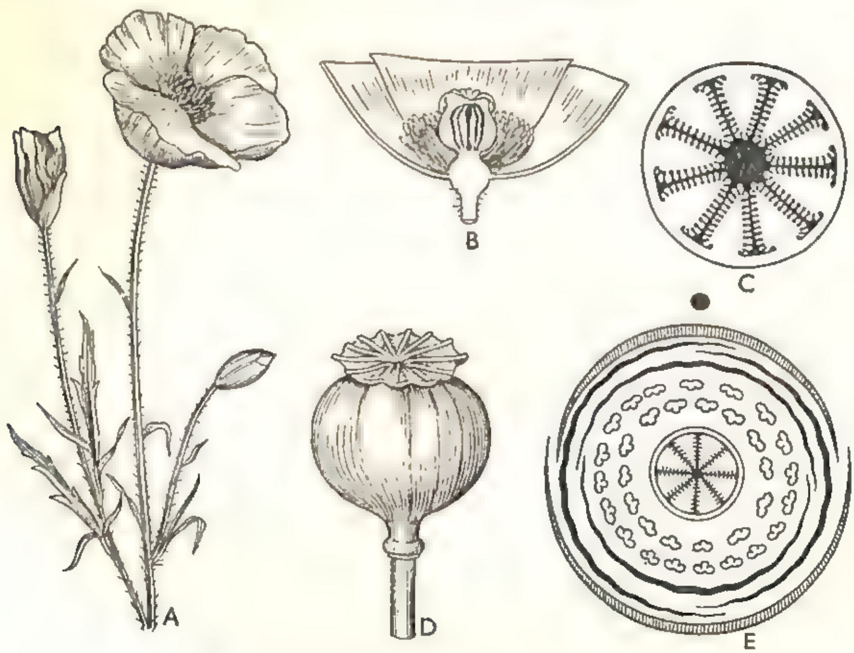


Fig. 550. Papaveraceae (*Papaver orientale*).
A, Portion of a flowering shoot; B, V.s. of a flower; C, T.s. of ovary; D. Fruit; E, Floral diagram.

KEY TO GENERA

Capsule opening by apical pore or valve

(*a*) Stigmas sessile, radiating from disc; capsule globose; floral symmetry 2 or its multiple; latex white .. .. *Papaver.*

(*b*) Stigmas arising from the depressed style; capsule oblong; floral symmetry 3 or its multiple; latex yellow .. .. *Argemone.*

(*c*) Stigmas decurrent with the style; capsule elongated; floral symmetry 2 or 3; latex yellow .. *Meconopsis.*

Common plants

(1) Opium poppy (*Papaver somniferum* L.), only white flowered forms are commonly cultivated for obtaining opium. (2) Mexican

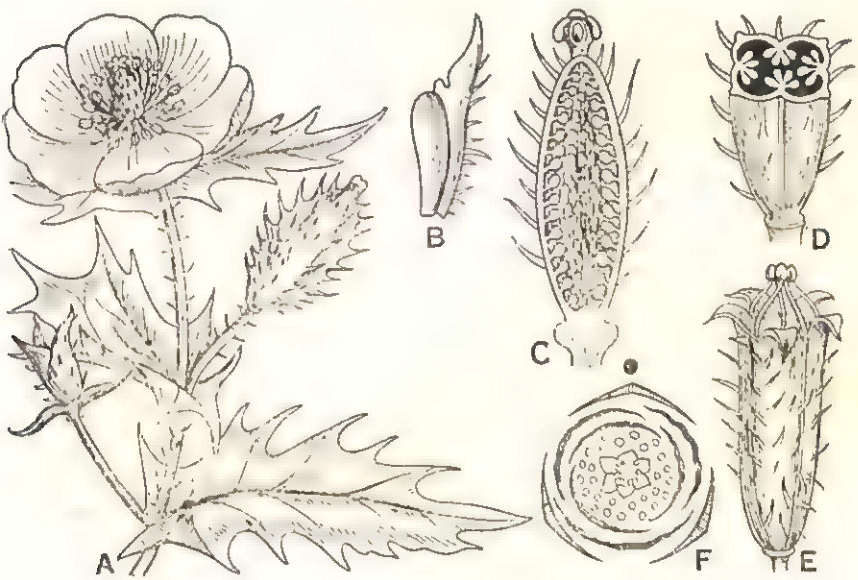


Fig. 551. Papaveraceae (*Agremone mexicana*).
A, Portion of a branch with flower and fruit; B, Sepal; C, L.s. of ovary; D, T.s. of the same; E, Fruit; F, Floral diagram.

poppy or Prickly poppy (*Argemone mexicana* L.), a prickly erect herb with yellow flowers which grows wild on roadsides and rice fields. (3) Oriental poppy (*Papaver orientale* L.) and (4) *P. argemone* L. are common garden annuals. (5) *Meconopsis nepalensis* DC. and *M. wallichii* Hook., are the commonly occurring plants in Darjeeling at a varying altitude of 8,000-11,000 ft.

Affinity

This family differs from Ranunculaceae by dimerous calyx, syncarpous ovary and milky or coloured latex. It forms a link with Cruciferae and Capparidaceae in the character of dimerous arrangement of the accessory sets and pod-shaped ovary, but differs from them in the character of the seed, and narcotic milky juice. It is also allied to Nymphaeaceae in the general structure of the flower. Papaveraceae is characterized by caducous calyx, usually crumpled corolla, numerous stamens in several whorls, unilocular ovary with parietal placentation and capsule fruit.

Economic importance

Papaveraceae is economically important. The opium of commerce is obtained from the sap of unripe capsules of *Papaver somniferum;* an alkaloid known as '*morphine*' is obtained from it. Some ornamental plants belong to the family. About 20 genera especially the Oriental poppy (*Papaver orientale*), Californian poppy (*Eschscholtzia* sp.), blue poppy (*Meconopsis* sp.), prickly poppy (*Argemone mexicana*), etc., are useful for decorative purposes.

CAPPARIDACEAE

General characters

Plants—chiefly herbs or shrubs, sometimes small trees (e.g., *Crataeva*) or climbing (e.g., *Capparis*), without latex. Leaves—usually alternate, simple or digitately 3-7 foliate, with or without stipules. Inflorescence—cymose, axillary or terminal, or racemose. Flowers—slightly irregular, rarely irregular (e.g., *Capparis*), bisexual (but unisexual in *Podandrogyne*), hypogynous, tetramerous, bracteate, *often with gynophore*, sometimes with androphore. Sepals——generally 4, free (sometimes more or less united), valvate or imbricate. Petals—usually 4, free, imbricate. Stamens—usually numerous, sometimes 8 or 6 (but *not tetradynamous*, e.g., *Gynandropsis*), rarely 4, free, with long filaments, sometimes supported on a stalk (androphore, e.g., *Gynandropsis*). Carpels—usually 2, sometimes 4; ovary superior, 1-celled with parietal placenta, but sometimes 2-chambered by replum (e.g., *Capparis*), usually supported on a long or short gynophore (excepting *Cleome*); ovules numerous and campylotropous. Fruit—siliquose (e.g., *Cleome*), capsule or berry (e.g.,

Capparis), rarely nut. Seeds—reniform, albuminous with curved embryo.

Number and distribution

This family consists of 46 genera and about 700 species which are abundantly found in the tropics and subtropics.

Fig. 552. Capparidaceae (*Cleome viscosa*).
A, Portion of a branch with flower and fruit; B, Flower; C, The same after removal of calyx and corolla; D, Stamen; E, T.s. of ovary; F, Fruit; G, Seed; H, Floral diagram.

KEY TO GENERA

A. Fruit capsular; plants usually herbs

(*a*) Stamens 12-20, sessile; corolla imbricated in bud; leaves digitately compound .. .. *Cleome*.

(*b*) Stamens 6 on androphore; corolla open in bud; leaves compound; 5-7-foliate .. .. *Gynandropsis*.

B. Fruit berry or capsule

(*c*) Disc present below sepaline tube; sepals 4, open in bud; plants usually small trees .. .. *Crataeva*.

(*d*) Disc hemispheric; sepals 4, 2-seriate: stamens 8-numerous, long, purple, inserted at the base of the gynophore: plants climbing with spinous stipule .. *Capparis*.

Range of floral structures

This family also shows variations in their floral structure. *Cleome tetrandra* represents the most reduced type of flower, where two sepals are outer, and two inner are transverse. The four petals are found to be diagonally placed. Ovary consists of 2 carpels. Variations may occur from this plan by the multiplication of the median stamens alone, or both median and lateral, or by conversion of one or more stamens into petaloid staminodes. Suppression of floral parts may sometimes occur. The flower of *Cleome spinosa* resembles that of a

Fig. 553. Capparidaceae (*Gynandropsis pentaphylla*).
A, Portion of a flowering shoot; B, Flower; C, Seed; D, Floral diagram.

cruciferous one in its horizontal plan but the tetradynamous stamens never occur in the family Capparidaceae. The multiple stamens sometimes develop in certain genera by the serial and lateral splitting of the 4 stamens, e.g., *Capparis*.

Zygomorphy of flower is attained due to unequal development of members. In *Pteropetalum*, the posterior petals are larger than the

anterior ones. In many species of *Capparis* the posterior sepal develops a hood-like structure; in *Emblingia* the formation of a 4-lobed calyx takes place by the union of sepals below. The sepals are generally found to be free, but occasionally they are united below.

The members of corolla are generally free. But in the anomalous genus *Emblingia*, the petals are united. In many a genera the petals are lacking.

The pistil is carried upon the long gynophore. It consists of two, rarely several carpels, forming a 1-celled ovary. This 1-chambered ovary may sometimes become multilocular by the growth of parietal placentae inwards.

Common plants

(1) *Cleome viscosa* L. = *Polanisia viscosa* DC., a common glandular weed, with yellow flowers, found everywhere. (2) *Gynandropsis pentaphylla* DC. = *G. gynandra* Briq., a common weed of waste and cultivated places with white flowers. (3) *Capparis sepiaria* L., a climbing plant chiefly found in scrubby jungles. (4) *Capparis horrida* L. f., *C. zeylanica* L. = *C. brevispina* DC., caperbush (*C. spinosa* L.) are also common weeds. (5) *Crataeva religiosa* Forst., a small tree, commonly found in villages.

Affinity

Phylogenists are of opinion that the Capparidaceae and Cruciferae are two closely related families. The former is readily distinguished from the latter by the slightly irregular flower, with 6 to many stamens, the presence of gynophore(and sometimes of androphore) and 1-celled ovary.

Economic importance

Some plants of this family possess medicinal properties. The dried flower-buds of *Capparis spinosa* are the 'capers' of economic use. Some species are used as ornamentals, such as *Capparis horrida*, *Cleome viscosa*, *Gynandropsis pentaphylla* and *Crataeva religiosa*.

CRUCIFERAE

General characters

Plants—annual or biennial herbs, often with *pungent watery juice*. Leaves—*radical* or *cauline* (usually *alternate*), simple, more or less

lobed, exstipulate with 1-celled simple or branched hairs. Inflorescence—usually a *raceme*, sometimes corymb (e.g., *Iberis*), ebracteate. Flowers—bisexual, regular (irregular in *Iberis*), actinomorphic, hypogynous. Sepals—2+2, free, imbricate. Petals—4, free, *cruciform*, clawed, imbricate or twisted. Stamens—2+4, *tetradynamous*, with nectaries present at the base of long stamens. Carpels—(2); ovary superior, 1-celled with parietal placentation, but afterwards 2-celled by a false septum (*replum*) connecting the two parietal placentae; ovules many, anatropous or campylotropous. Fruit—usually a *siliqua*, sometimes a silicula. Seeds—numerous, round, exalbuminous, oily with curved embryo.

Number and distribution

This family consists of 350 genera and about 2,500 species which are chiefly found in the North temperate regions and in the plains during winter.

Key to Genera

A. Fruit indehiscent

(*a*) Pod long, hollow or septate, breaking into 1-seeded fragments; seeds globose; sepals pouched at the base .. *Raphanus.*

(*b*) Pod short, globose; sepals spreading, not pouched at the base .. .. *Senebiera.*

B. Fruit dehiscent

(*c*) Pod short, cylindric; seeds minute, biseriate; sepals spreading; stigma shortly divided; fls. yellow .. *Nasturtium.*

(*d*) Pod short, flattened, acute, unnerved; seeds uniseriate; sepals erect; fls. white .. .. .. *Cardamine.*

(*e*) Pod with indehiscent beak; cotyledons incumbent or folded

(*i*) Beak cylindric or conical; seeds uniseriate; sepals yellow, pouched at the base and marked with green veins .. .. .. *Brassica.*

(*ii*) Beak flattened; seeds biseriate; sepals lilac, pouched at the base .. .. .. *Eruca.*

Range of floral structures

The regular flowers (e.g., *Brassica, Raphanus*) are *bisexual* and *hypogynous*, with *four free sepals* in two whorls, median and transverse, and *four free diagonally placed petals.* The androecium typically of 6 stamens in 2 whorls, usually tetradynamous. The pistil consists of

2 transversely-placed carpels bearing a double row of pendulous, campylotropous ovules on the parietal placentae formed at two sutures.

Departures from the normal type of flower occur. In *Iberis* and *Teesdalia* the flower becomes zygomorphic by the enlargement of the two outer petals. The petals are infrequently small or absent totally, as in species of *Lepidium*, *Coronopus*, *Nasturtium* and others; in *Capsella bursa pastoris*, the petals are occasionally replacéd by 4 stamens.

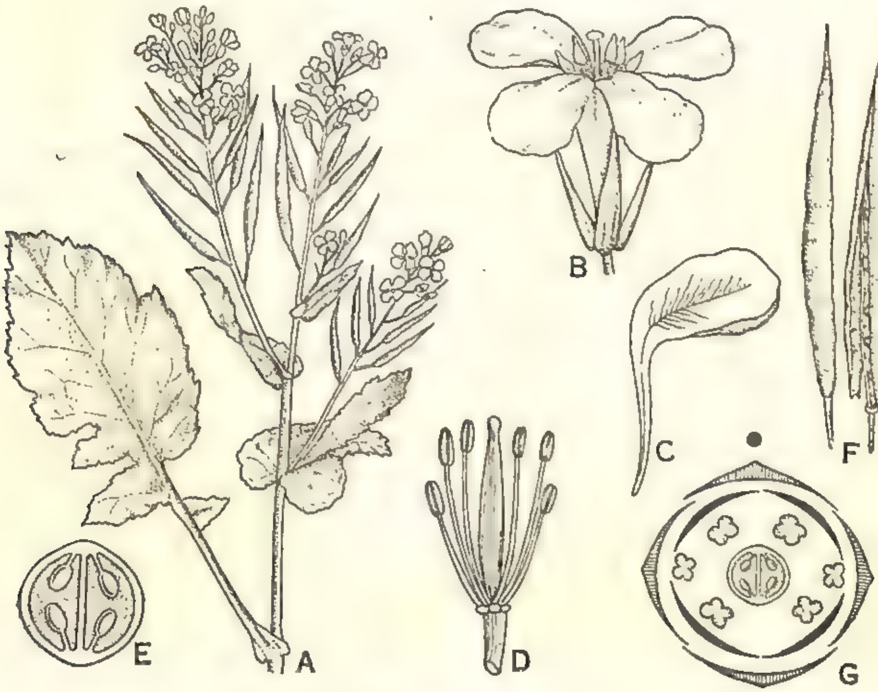


Fig. 554. Cruciferae (*Brassica nigra*).
A, Portion of a flowering shoot; B, Flower; C, Petal; D, Tetradynamous stamens; E, T s. of ovary; F, Fruit; G, Floral diagram.

Reduction in the number of stamens is also found to occur. In *Cardamine hirsuta*, the lateral stamens are generally absent; in species of *Lepidium* and *Coronopus* doubling of the median stamens may also fail to take place and the flower ultimately becomes diandrous. In the asiatic genus *Megacarpaea*, the number of stamens reaches upto 16.

Three or four carpels occur abnormally in many genera of Cruciferae. The genera *Tetrapoma* and *Holargidium* have four- (or more) carpelled ovary. *Lepidium sativum* represents the tricarpellary

pistil. Multicarpellary pistils have also been recorded in abnormal flowers in a considerable number of genera.

The pistil sometimes presents difficulties in the almost universal position of the stigmas above the commissure, or the vertical line of tissue at the junction of the two carpels, and in the presence of false septum. In *Matthiola incana* and *Moricandia* the stigmas occupy the usual position above the midrib of the carpel.

Common plants

(1) Mustard plants, e.g., Mustard or Indian Rape (*Brassica napus* L.), White mustard (*B. alba* Hook. & T.), Black mustard (*B. nigra* Koch. = *B. juncea* Hook. & Thom.), are all cultivated for oil. (2) Radish (*Raphanus sativus* L.), is cultivated for the swollen fleshy root. (3) Turnip (*Brassica campestris* L.), is taken as a vegetable. (4) *Nasturtium indicum* DC. = *Rorippa montana* Small, a weed. (5) Candytuft (*Iberis amara* L.), a common garden plant. (6) Cauliflower, cabbage, knol-kohl and broccoli are the different varieties of *Brassica oleracea* L., which are cultivated as vegetables. (7) *Cardamine debilis* Don., a garden weed of the cold weather. (8) *Eruca sativa* Lamk., a cold weather crop is occasionally cultivated. (9) Shepherd's purse (*Capsella bursa pastoris* Moench.), a common weed. (10) *Senebiera pinnatifida* DC. = *Coronopus didymus* Sm., a common weed in garden and roadside.

Affinity

Phyletically, the position of Cruciferae is in the Rhoedales. But there are discrepancies of opinion between Bentham & Hooker and Hutchinson, as to whether it has been derived from papavarous ancestors or from capparidaceous ancestors. Capparidean alliance is more tenable being based on the morphology of androecium and gynoecium and anatomy therein. However, this family can be readily distinguished from Capparidaceae by having cruciform corolla, tetradynamous stamens, the absence of a gynophore, and the nature of the fruit. It is also related to Papaveraceae.

Economic importance

There is considerable importance of the family for the production of fodder crops, weeds and ornamentals. The most important and edible food crops are cabbage, cauliflower, broccoli, brussel's sprouts, kohlrabi, turnip and radish. Economic weeds include mustards

(*Brassica*), shepherd's purse (*Capsella*) and pepper grass (*Lepidium*). Oil is extracted from the mustard seeds and the oil-cake is used as manure and fodder. The table mustard is obtained from the seeds of black and white mustards. The ornamental plants are stocks (*Matthiola*), candytuft (*Iberis*), wallflower (*Cheiranthus*), etc.

Comparison between Cruciferae and Capparidaceae

Cruciferae	*Capparidaceae*
1. Leaves—radical or cauline, simple, lobed or pinnatifid, exstipulate.	1. simple or palmately compound, with or without stipules.
2. Flowers—regular, ebracteate.	2. slightly irregular, bracteate, usually with gynophore and sometimes with androgynophore.
3. Petals—4, cruciform.	3. 4, but never cruciform.
4. Stamens—6, tetradynamous.	4. numerous, sometimes 8 or 6 (but never tetradynamous), rarely 4.
5. Ovary—1-celled, but afterwards 2-celled by replum.	5. 1-celled but sometimes chambered by replum.
6. Fruit—siliqua or silicula.	6. siliquose or berry.

ORDER 21. ROSALES

Flowers bisexual (unisexual by abortion), cyclic, regular (sometimes zygomorphic), typically pentamerous, hypogynous to epigynous (usually perigynous). Stamens numerous in many whorls, usually free. Carpels numerous, free or united, but the styles generally distinct.

According to Engler this Order consists of 3 suborders containing 17 families, *viz.*, Crassulaceae, Rosaceae, Leguminosae, etc. Bentham and Hooker have placed the aforesaid families in the cohort Rosales under the subclass Polypetalae. In Hutchinson's system Crassulaceae has been put under the Order Saxifragales (the 14th Order). The Order Rosales contains 3 families only and is the 40th Order of his system. Leguminosae is designated as an Order (41st Order) consisting of 3 families, *viz.*, Caesalpinieae, Mimosae and Papilionaceae.

CRASSULACEAE

General characters

Plants—annual or perennial herbs or undershrubs with *succulent stems*. Leaves—alternate, sometimes opposite or whorled,

simple, entire but sometimes lobed, *succulent*, usually persistent, exstipulate. Inflorescence—usually cymose, sometimes spike or panicle. Flowers—regular, bisexual (sometimes unisexual), hypogynous. Sepals—4, sometimes 5, free (but united in *Kalanchoe*), valvate or imbricate. Petals—4, sometimes 5, free, valvate or imbricate. Stamens—*as many as or twice as many as the petals in two whorls*, situated on a swollen or cup-like disc, free. Carpels—*usually equal to the*

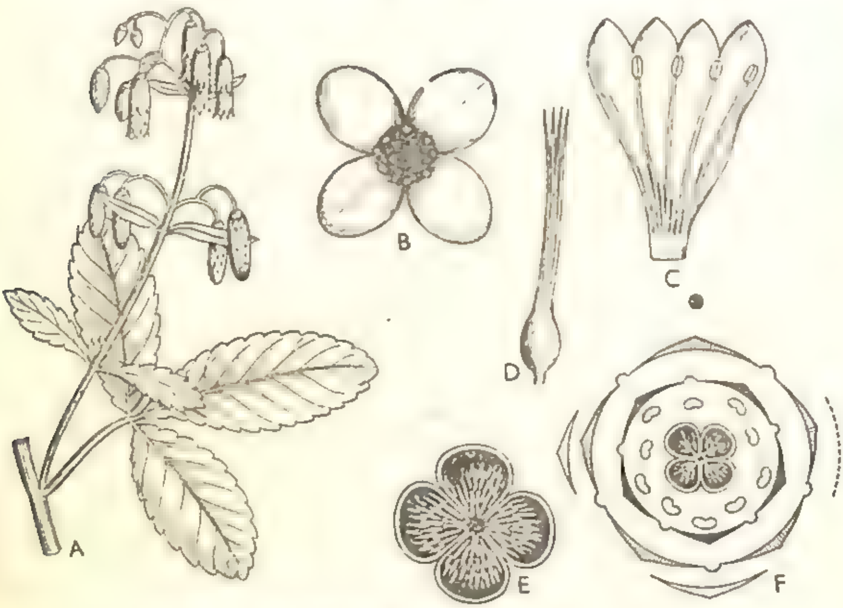


Fig. 555. Crassulaceae (*Bryophyllum calycinum*).
A, Portion of a flowering shoot; B, Flower; C, Corolla split open; D, Pistil; E, T.s. of ovary; F, Floral diagram.

number of petals, free or united below, *each usually subtended by a scale-like nectar gland at the base;* ovary superior, 1-celled with parietal placentation. Fruit—*follicle*. Seeds—with fleshy endosperm and straight embryo.

Number and distribution

This family consists of 30 genera with about 1,300 species, which are widely distributed in the world excepting Australia and Oceania.

Key to Genera

Calyx with a long inflated tube and a shortly 4-fid limb; corolla tube campanulate with a shortly 4-fid limb .. *Bryophyllum*.

Calyx with a short tube and deeply 4-partite limb; corolla tube flask-like with a spreading, 4-fid limb .. .. *Kalanchoe*.

Common plants

(1) *Bryophyllum calycinum* Salisb., a stout fleshy herb. (2) *Kalanchoe heterophylla* Prain, a stout fleshy herb, chiefly found in Pareshnath

Fig. 556. Crassulaceae (*Kalanchoe spathulata*).
A, Portion of a flowering shoot; B, Flower; C, Corolla split open; D, Pistil; E, T.s. of ovary; F, Fruit; G, Floral diagram.

Hill. (3) *K. laciniata* Adams., found in E. Pakistan, Behar and other places. (4) *K. spathulata* Adams., a common weed.

Affinity

This family is readily distinguished from others by the succulent character of stems and leaves, the gynoecium composed of usually as many carpels as there are petals, a like number of stamens in each whorl and by the presence of scale-like gland at the base of each carpel.

Economic importance

This family is of little economic importance. Some are planted in our gardens as ornamentals.

ROSACEAE

General characters

Plants—herbs, shrubs or trees (e.g., Apple, Pear, Cherry, Plum, Loquat, etc.), sometimes climbing, often prickly. Leaves—alternate, usually pinnately compound, stipulate (*adnate stipules*). Inflorescence—cymose. Flowers—regular (but sometimes irregular, as in *Chrysobalanus*), usually bisexual (unisexual in *Aruncus*), *perigynous*, sometimes epigynous, with *odd sepal posterior*. Sepals—(4-5), imbricate. Petals—4-5, free, imbricate. Stamens—free (but monadelphous in *Chrysobalanus*), usually numerous, in 1-many whorls of 5 stamens, sometimes 5 or 10; bent inwards in bud, perigynous (but epigynous in *Pyrus*, *Eriobotrya*). Carpels—1 (e.g., *Prunus*) to numerous, free or united; ovary superior or inferior (e.g., *Pyrus*), 1-celled or 2-5 celled, usually with 2 pendulous or ascending, anatropous ovules. Fruit—drupe, pome or aggregate of follicles or achenes or berries. Seed—generally without endosperm. Embryo—plano-convex, often with fleshy cotyledons.

Number and distribution

This family consists of about 115 genera and 3,200 species which

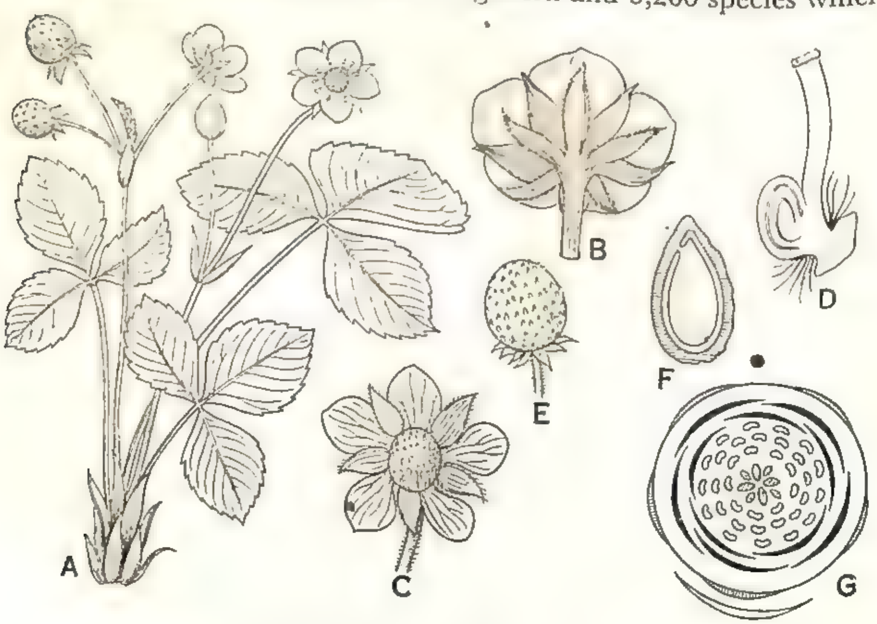


Fig. 557. Rosaceae (*Fragaria vesca*).
A, Portion of a flowering shoot; B, Flower as seen from the underside; C, Flower; D, L.s. of a carpel; E, Fruit; F, Seed; G, Floral diagram.

are chiefly found in the temperate regions (in India in the Northern Himalayas).

KEY TO GENERA

A. Ovary superior; ripe carpels not enclosed within the calyx-tube

(a) Carpel solitary

(i) Leaves simple, quite entire, fruit 2-seeded .. *Pygeum*.

(ii) Leaves simple, serrate, fruit 1-seeded .. *Prunus*.

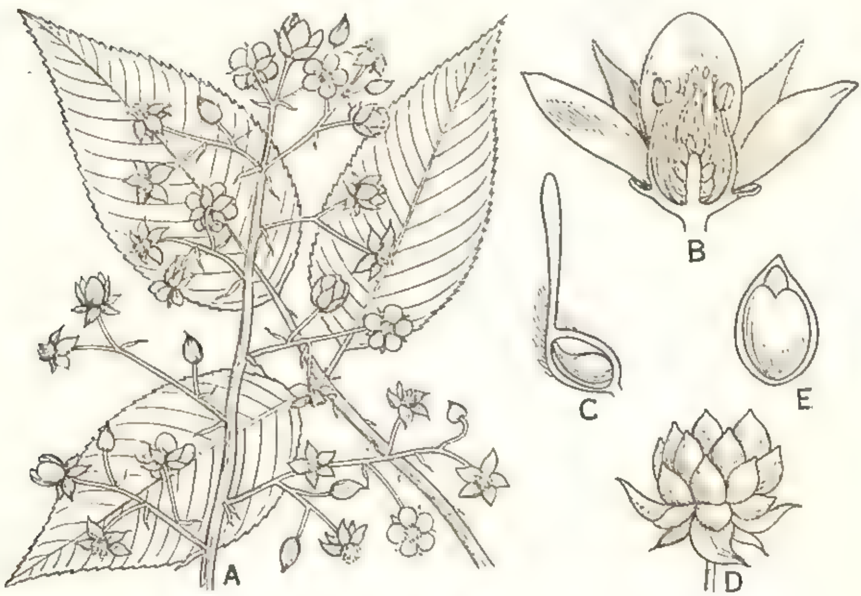


Fig. 558. Rosaceae (*Rubus hexagynous*).
A, Portion of a flowering shoot; B, V.s. of a flower; C, Carpel; D, Fruit; E, L.s. of a seed.

(b) Carpels many

Unarmed herbs; ripe carpels dry; ovules solitary

(i) Leaves compound, fruit achenes on fleshy receptacle .. .. .. *Fragaria*.

(ii) Leaves compound, fruit achenes on dry receptacle .. .. *Potentilla*.

Armed shrubs; leaves simple or compound, with stipules adnate or free; carpels many or few on a convex receptacle; fruit drupe .. .. *Rubus*.

B. Ovary inferior; ripe carpels enclosed within the calyx-tube

(*c*) Carpels many, not confluent when ripe

Armed shrubs; leaves compound with adnate stipules; fruit a fleshy calyx-tube enclosing bony achenes .. *Rosa.*

Shrubs or trees; leaves simple, coriaceous, usually serrate; flowers white, panicled; fruit an one-seeded dry or succulent berry, endocarp membraneous .. *Eriobotrya.*

Shrubs or trees; leaves simple or compound; flowers white, red or pink, in terminal corymbs .. *Pyrus.*

Range of floral structures

This family has wide range of variation in the construction of flowers regarding the structure of thalamus, union of carpels and the structure of fruit.

It has been divided into six subfamilies according to the floral construction by Focke.

Subfamily I. Spiraeoideae

The receptacle or thalamus is somewhat flat but never forms a deep cup or convex structure. Carpels—5, free, situated in the centre. Stamens—10-many. Fruit—a follicle or capsule. Example—*Spiraea*, found in the Eastern Himalayas.

Subfamily II. Pomoideae

The thalamus is deeply concave. Carpels—2-5, more or less united and adnate to the thalamus (inferior ovary); each carpel contains two ovules. The flowers are usually epigynous. Fruit—a pome. Example—*Pyrus malus* (Apple).

Subfamily III. Rosoideae

The thalamus is concave in nature. Carpels—many and free, situated in the cup-shaped thalamus, as in *Rosa*, or the thalamus becomes swollen and convex, or slightly elongated, as in *Rubus*, on which many free carpels are seated. Each carpel contains 1 or 2 ovules. Examples—*Rosa alba*, a common garden rose, *Potentilla fulgens* found in the Eastern Himalayas, *Fragaria vesca* (Strawberry), *Rubus hexagynous* (Bramble).

Subfamily IV. Neuradoideae

Thalamus is cup-shaped. Carpels—5-10, united at the base. Example—*Neurada procumbens.*

Subfamily V. Prunoideae

Flowers regular. Thalamus is cup-shaped. Stamens—10, 20 or many. Carpel—1, contains two pendulous ovules. Style—terminal. Fruit—drupe or berry. Example—*Prunus.*

Subfamily VI. Chrysobalanoideae

Flowers are irregular. Thalamus is deeply cup-shaped. Stamens—10-15 or more; filaments are united. Carpel—one; ovules erect; style basal. Fruit—berry. Example—*Chrysobalanus.*

Common plants

(1) Cabbage rose (*Rosa centifolia* L.), Wild rose of Bengal (*R. involucrata* Roxb.), *R. damascena* Mill., commonly cultivated for

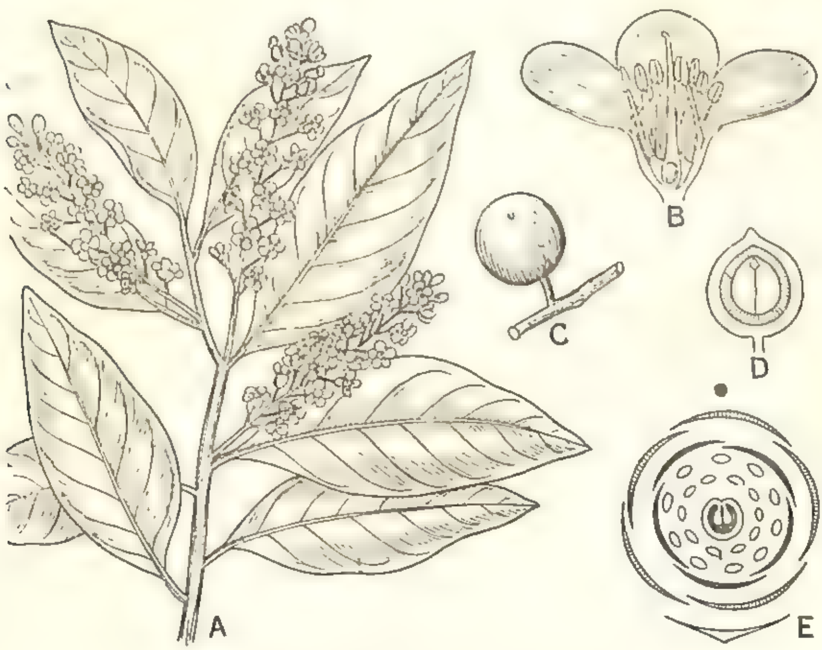


Fig. 559. Rosaceae (*Prunus persica*).
A, Portion of a flowering shoot; B, V.s. of a flower; C, Fruit; D, L.s. of the same; E, Floral diagram.

attar, *R. indica* L., a small spreading shrub frequent in gardens, White rose (*R. alba* L.). (2) Cherry (*Prunus cerasus* L.). (3) Plum (*P. domestica* L.). (4) Apricot (*P. armeniaca* L.). (5) Peach (*P. persica*

Benth. & Hook. f.). (6) Hudson Almond (*P. amygdalis* L.). (7) *Prunus bokhariensis* Royle. (8) *Prunus puddum* Roxb. = *P. cerasiodes* D. Don., very common in the hills. (9) Apple (*Pyrus malus* L.). (10) Pear (*P. communis*). (11) Loquat (*Eriobotrya japonica* Lindl.), a small tree cultivated for its delicious fruit. (12) Indian strawberry (*Fragaria nilgerrensis* Schldl.) and Strawberry (*F. vesca*) are trailing herbs commonly found on the hills. (13) *Pygeum acuminatum* Coleb., a tree. (14) *Potentilla supina* L., *P. fulgens* and *P. nepalensis* Hook. are annual

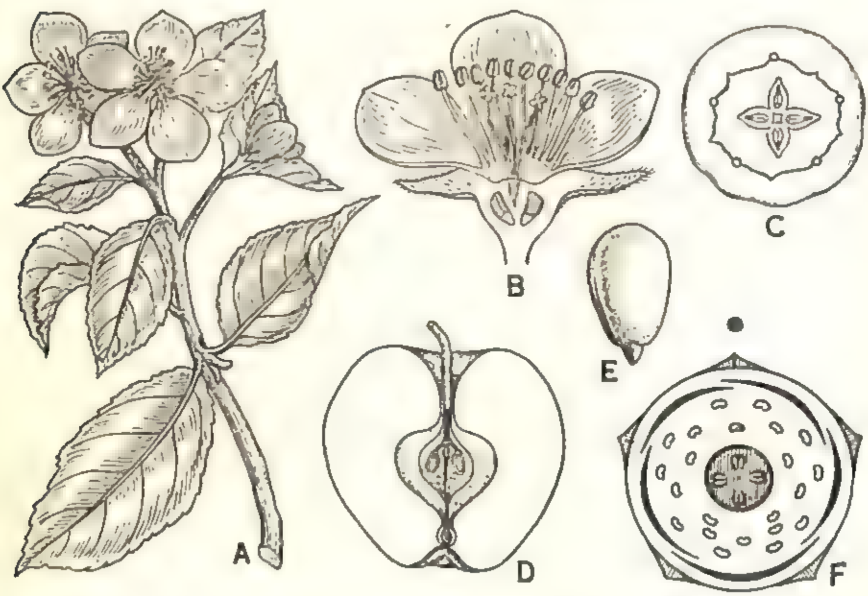


Fig. 560. Rosaceae (*Pyrus malus*).
A, Portion of a flowering shoot; B, V.s. of a flower; C, T.s of fruit; D, L.s. of fruit; E, Seed; F, Floral diagram.

herbs commonly found in Darjeeling, Shillong and other hilly stations. (15) Bramble (*Rubus hexagynous* Roxb.), a climbing shrub with flat prickles. (16) Blackberry (*Rubus fruticosus* L.), a suberect rambling shrub, commonly found in the Himalayas.

Affinity

This family is closely allied to Ranunculaceae from which it is readily distinguished by the presence of stipules, usual perigynous flower and cyclic arrangement of stamens. It is distinguished from Leguninosae by the position of odd sepal.

Economic importance

This family is of great importance from economic point of view. Most of the members are fruit-producing plants. *Frageria vesca* produces strawberry, *Pyrus malus* yields apple. Pear is obtained from *Pyrus communis; Prunus armeneaca* and *P. persica* yield apricot and peach respectively. Almonds are obtained from the seeds of *Prunus amygdalis*. Many plants are useful for ornamental purposes, such as *Spiraea, Cotoneaster, Crataegus, Rosa, Potentilla, Prunus,* etc.

LEGUMINOSAE

General characters

Plants—herbs, shrubs or trees, sometimes *with tubercles* on roots. Leaves—alternate, *usually compound, stipulate*. Flowers—*always lateral*, bisexual, regular or irregular, *slightly perigynous;* odd *sepal anterior*. Carpel—one; ovary superior, *1-celled* with *marginal placentae*, bearing ovules in two alternating rows along the ventral suture. Fruit—usually a *legume*, sometimes lomentum. Seed—exalbuminous. Embryo—consists of two large flat cotyledons.

Number and distribution

This family consists of about 550 genera and more than 12,000 species which are widely distributed all over the globe, particularly in the tropics.

Subdivisions of the Family

Leguminosae is the second largest family of flowering plants. Hence, it has been divided into three subfamilies—(*a*) **Papilionaceae,** (*b*) **Caesalpinieae** and (*c*) **Mimosae,** the differences being based upon the characters of the corolla and he androecium.

Range of floral structures

This family exhibits a good deal of variation in the arrangement and form of the segments of perianth, particularly of corolla. There has been observed much wide variations in the number and cohesion of the androecium.

The *subfamily Papilionaceae* is characterized by the presence of the prominent zygomorphic and papilionaceous flowers. The sepals

are generally connate and their aestivation is imbricate. The number of petals is 5 and they are unequal with vexillary aestivation. The outermost (posterior) petal becomes the biggest, forming the standard (*vexillum*), the lateral pair forms the wings (*alae*) and the anterior pair forms the keel (*carina*). In the genus *Amorpha*, the wings and keel are not found.

The number of stamens is 10; they are usually diadelphous, sometimes monadelphous, as in *Crotalaria*, *Arachis*; they are in two bundles of 5 each, as in *Aeschynome*. Sometimes the posterior stamen is obliterated, as in *Chorizema*.

The *subfamily Caesalpinieae* contains 133 genera. Flowers are usually medianly zygomorphic and they are either penta- or tetramerous. In *Tamarindus*, two upper sepals are connate, but in other genera the sepals are free and with imbricate aestivation. But *Cercis* represents the valvate type of aestivation. There also occurs variation in the pentamerous corolla. In *Cassia*, the 5 petals are subequal. The anterior pair of petals becomes small or suppressed, as in *Amherstia nobiles*. In *Krameria*, the glandular scales represent the anterior pair of petals. They are obliterated in *Tamarindus*. Species of *Ceratonia* and *Copaifera* are without petals.

The last *subfamily Mimosae* contains 40 genera. Flowers are usually regular. Valvate type of aestivation is manifested by both calyx and corolla, but imbricate type of aestivation is found in *Parkia*. The number of perianth is 5, but tri-, tetra- or hexa-merous flowers do occur. In *Mimosa pudica*, the flower is tetramerous but in *Acacia* the flower may be tri- or tetra-merous. The stamens also show a great variation in their number. The stamens are numerous and free as in *Acacia*; numerous and more or less forming a single bundle (monadelphous) as in *Inga*.

A marked variation in the number of carpels is found to occur here and there in some genera. The carpel is usually single and median. Two carpels are found in the genus *Tounatea* (Caesalpinieae). Some under the tribe Ingeae (Mimoseae), *Medicago* (Papilionaceae) have only single carpel.

The styles are terminal and bending in two subfamilies Caesalpinieae and Papilionaceae, but the straight or rolled styles occur in *Phaseolus*.

The ovules are either amphitropous or anatropous, occasionally campylotropous. They are either ascending or pendulous having one or two integuments.

SUBFAMILY 1. PAPILIONACEAE

Characters

Leaves—usually imparipinnate. Flowers—solitary or in racemes, very irregular (*papilionaceous*), posterior petal biggest and outer-

Fig. 561. Papilionaceae (*Trigonella corniculata*).
A, Portion of a flowering shoot; B, Flower; C, Petals; D, Flower with sepals and petals removed; E, Pistil; F, T.s. of ovary; G, Fruit; H, Floral diagram.

most. Petals—5, *vexillary* in aestivation. Stamens—10, *usually diadelphous* (9)+1, sometimes monadelphous (e.g. *Arachis*, *Crotalaria*, etc.), rarely 9 (e.g. *Abrus*). Embryo—curved.

KEY TO GENERA

A. Stamens free

(*a*) Straggling or scandent shrubs; leaves 1-foliate; bracteoles large, hiding flowers .. .. *Dalhausiea.*

(*b*) Shrubs; leaves imparipinnate; bracteoles 0 .. *Sophora.*

(*c*) Erect trees; leaves imparipinnate; bracteoles minute *Ormosia.*

B. Stamens monadelphous

(*a*) Prostrate herbs (cultivated): leaves pinnately compound with 2 pairs of leaflets; fruit hypogeal, burrying itself to ripen underground .. .. .. *Arachis.*

(*b*) Annual herbs; leaves digitately 3- or 4-foliate, gland dotted .. .. *Zornia.*

(*c*) Herbs or shrubs; leaves simple, sessile, or digitately 3-7-foliate; fruit turgid, non-septate, dehiscent .. *Crotalaria.*

(*d*) Stem woody and twining; leaves paripinnate; stamens (9), vexillary filament absent .. *Abrus.*

(*e*) Large twining or prostrate herbs

(*i*) Leaves pinnately 3-foliate .. .. *Canavalia.*

(*ii*) Leaves pinnately 3-foliate, leaflets lobed .. *Pueraria.*

(*iii*) Leaves pinnately 3-foliate, 5 alternate stamens sterile .. .. *Teramnus.*

C. Stamens diadelphous

Herbs; pods dehiscent by both sutures

(*a*) Leaves paripinnate, rachis ending in a bristle or tendril.

Leaflets deeply toothed; pod turgid, sessile, tipped with beardless style .. .. *Cicer.*

(*C. arietinum* has usually a terminal leaflet instead of a tendril).

Leaflets entire, rachis ending in a twisted tendril, staminal tube oblique at its mouth

(*i*) Style bearded at the tip; ovule usually more than two; pod compressed .. .. *Vicia.*

(*ii*) Style longitudinally bearded along inner surface; ovules never more than two; fruit a compressed 1-2-seeded pod; seeds compressed; cotyledons pink .. .. .. *Lens.*

(*iii*) Style flat, bearded along inner face and dilated above; fruit many-seeded pod, compressed .. *Lathyrus.*

(*iv*) Style 3-cornered, dilated upwards; pod turgid *Pisum.*

Herbs; pods indehiscent or dehiscent along the ventral suture

(*b*) Leaves pinnately 3-foliate, veins produced as marginal teeth in leaflets, stipules adnate—

(*i*) Flowers yellow or white; pod nearly round, 1 or 3-seeded .. .. *Melilotus.*

(*ii*) Flowers usually purple, violet or blue, sometimes yellow; pods larger than calyx, downy and loosely spiral .. .. *Medicago.*

(*iii*) Flowers white or yellow; pod long, thin and jointed .. .. *Trigonella.*

(*iv*) Flowers usually reddish or purple; pod slender, 1 or more-seeded .. .. .. *Indigofera.*

(*v*) Flowers blue; pod 1-seeded, indehiscent .. *Psoralea.*

Herbs or undershrubs; leaves pinnate, sensitive, 3-5 pairs, exstipulate, the rachis ending in a bristle or leaflet; flowers bright yellow; stamens in 2-bundles of 5 each; fruit a lomentum, folded inside the calyx .. .. *Smithia.*

Undershrubs growing in jheels and ditches, soft-wooded; leaves imparipinnate, numerous, sensitive; flowers bright yellow or orange yellow; stamens in 2 bundles of 5 each; fruit a long lomentum, exserted .. *Aeschynomene.*

Herbs or undershrubs; leaves stipulate, leaflets 1-9; stamens (9)+1; fruit lomentum, coiled and more or less folded within the calyx .. .. .. *Uraria.*

Herbs or undershrubs; leaves 3-1 foliate; pod flat not coiled; stamens (10) or (9)+1 .. .. *Desmodium.*

Herbs or undershrubs; leaves pinnately 3-foliate, not glandular beneath

Twining, style bearded below stigma—

Keel spirally twisted; stigma oblique .. .. *Phaseolus.*

Keel not spiral; stigma oblique .. .. *Vigna.*

Leaflets lobed, stigma oblique, tuberous rootstocks .. *Pachyrhizus.*

Stigma terminal; pod flattish, winged .. .. *Dolichos.*

Pod square, winged .. .. *Psophocarpus.*

Standard shorter than keel and wings; pods usually beset with stinging hairs .. .. .. *Mucuna.*

Trees with prickly branches; keel and wings shorter than standard; leaflets more or less cordate .. .. *Erythrina.*

Trees or woody climbers; flowers large showy, orange-red; calyx silky, wings free from keel .. .. *Butea.*

Woody twiners; flowers small; corolla not much larger than calyx; wings adnate to the keel .. .. *Spatholobus.*

(*c*) Leaves pinnately 5 or more foliate with terminal leaflet

(*i*) Pod flat, indehiscent.

Woody climbers or trees—

Leaflets alternate; stamens (9)+1 or (10) or (5)+(5) .. .. .. *Dalbergia.*

Timber trees; flowers yellow—

Leaflets alternate; stamens as above; pod thin, orbicular .. .. *Pterocarpus.*

Trees; leaflets opposite; flowers pink or white; ovary 2-ovuled; pod almost woody, wingless.. *Pongamia.*

(*ii*) Pod dehiscent

Herbs or shrubs, usually climbing

Flowers blue, white or purple; standard spoon-shaped; stamens (9)+1 or (10); anthers uniform .. .. .. *Clitoria.*

Erect herbs or undershrubs, more or less hairy with an offensive smell; leaflets imparipinnate, with 6-10 pairs; flowers red or purple .. *Tephrosia.*

Herbs, shrubs or soft-wooded trees, sometimes prickly; leaves paripinnate; leaflets may be 40 pairs; flowers large, yellow, dotted with purple or white or red; roots with copious tubercles .. .. .. *Sesbania.*

Common plants

(1) Pulses: Pea (*Pisum sativum* L.), Gram (*Cicer arietinum* L.), Lentil (*Lens esculentus* Moench. = *L. culinare* Medic.), Pigeon pea (*Cajanus indicus* Spreng. = *C. cajan* Mill.), Chick pea (*Lathyrus sativus* L.), Green gram (*Phaseolus aurieus* L.), Black gram (*Phaseolus mungo* L.). (2) Vegetables: Windsor bean or Broad bean (*Vicia faba* L.), Lablab or Black bean (*Dolichos lablab* L.), Cow-pea (*Vigna catjang* Endl.). (3) Butterfly pea (*Clitoria ternatea* L.), a common perennial twiner of gardens. (4) Coral tree (*Erythrina indica* Lam. = *E. variegata* L.), a common tree planted along hedges. (5) *Sesbania grandiflora* Pers. (6) The flame of the forest (*Butea frondosa* Roxb. = *B. monosperma* Taub.), commonly planted for its beautiful flowers. (7) Ground-nut or Pea-nut (*Arachis hypogaea* L.), commonly cultivated for its edible seeds. (8) *Dalbergia sisso* Roxb., a timber tree. (9) Indian cork plant (*Aeschynomene aspera* L.), yields the 'shola' of commerce. (10) Indigo (*Indigofera tinctoria* L.), a dye-yielding plant. (11) Crab's eye or Indian Liquorice (*Abrus precatorius* L.), a perennial twiner,

the red and black seeds of which are used as small weights by the jewellers. (12) Red sandal wood (*Pterocarpus santalinus* L.), and Gum kino tree (*P. marsupium* Roxb.). are timber trees. (13) *Mucuna pruriens* DC., a semi-woody climber whose pods are provided with stinging hairs. (14) Telegraph plant (*Desmodium gyrans* DC. = *D. motorium* Merr.), a common weed of waste places, well-known for

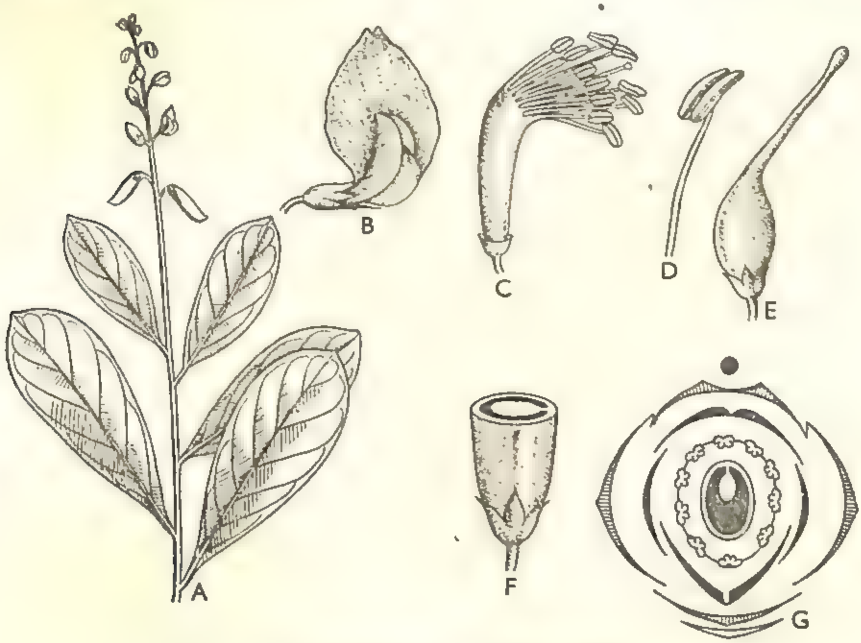


Fig. 562. Papilionaceae (*Crotalaria juncea*).
A, Portion of a flowering shoot; B, Flower; C, Monadelphous stamen; D, Stamen; E, Pistil; F, T.s. of ovary; G, Floral diagram.

its variation movements. (15) Sunn-hemp (*Crotalaria juncea* L.), a fibre-yielding plant; *C. retusa* L., a common garden plant. (16) Yam bean (*Pachyrhizus angulatus* Rich.), a climber with woody stems and large tuberous roots. (17) Sword bean (*Canavalia ensiformis* DC. = *C. gladiata* DC.), a large climber. (18) Hoary Pea or Wild Indigo (*Tephrosia purpurea* Pers.), commonly found in waste places and roadsides. (19) *Pongamia glabra* Vent. = *P. pinnata* Pierre., an avenue tree. (20) *Melilotus alba* Lamk. and *M. indica* All. are common field weeds in the cold season. (21) *Trigonella corniculata* L., an annual crop. (22) *Smithia sensitiva* Ait., commonly found in waste places. (23) *Uraria picta* Desv., found in grassy glades and fields (24) *Spatholobus roxburghii* Benth., a heavy woody climber. (25) *Medicago lupulina* L.,

a diffuse trailing herb; Alfalfa (*M. sativa* L.), a medicinal plant. (26) *Psophocarpus tetragonolobus* DC., a slender annual climber. (27) *Teramnus labialis* Spreng., an common slender twining plant. (28) *Pueraria tuberosa* DC., a shrubby climber with a large tuberous root. (29) *Zornia diphylla* Pers., an annual herb. (30) *Sophora bakeri* Clarke, a shrub. (31) *Ormosia robusta* Wight., a tree. (32) *Dalhousiea*

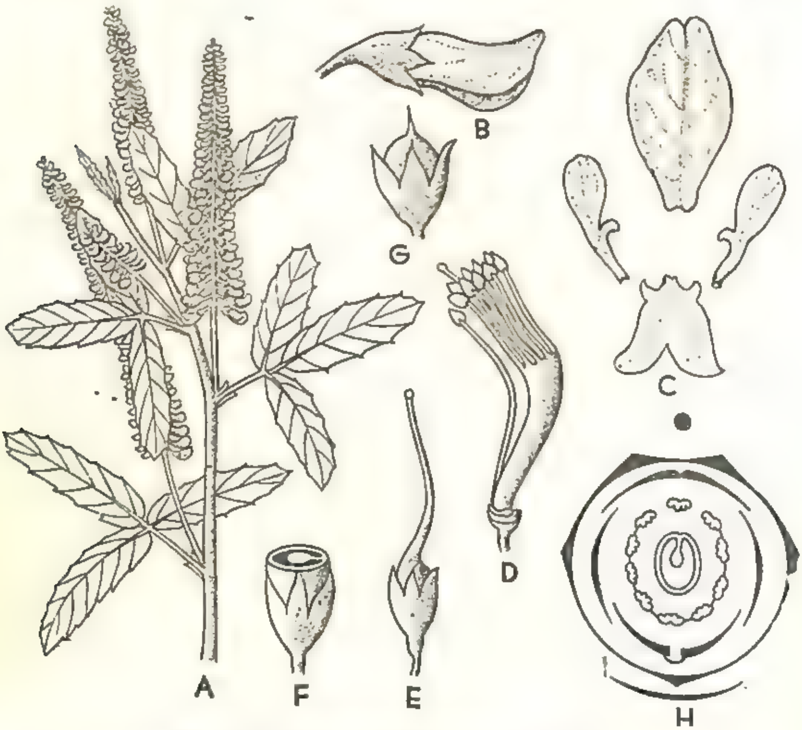


Fig. 563. Papilionaceae (*Melilotus alba*).
A, Portion of a flowering shoot; B, Flower; C, Petals; D, Flower with sepals and petals removed; E, T.s. of ovary; G, Fruit; H, Floral diagram.

bracteata, a scandent shrub. (33) *Psoralea corylifolia* L., a common erect annual, 1-3 ft. high. (34) *Glycyrrhiza glabra* L., a tall perennial plant. (35) *Ougenia dalbargioides* Benth., a tree with a short crooked trunk.

Economic importance

The plants of this subfamily have distinctly diverse properties (both purgative and poisonous). The pulses are the most important plants. Pods of *Cicer*, *Dolichos* and *Vigna* are used as table vegetables.

Dalbergia and *Pterocarpus* are important timber-producing trees. *Crotalaria* yields hemp-like strong fibres. *Indigofera* was formerly extensively cultivated for producing dye. *Butea* is chiefly used as a lac-rearing tree. Seeds of *Trigonella*, *Melilotus*, *Medicago*, *Psoralea* and *Glycyrrhiza* have medicinal importance. *Aeschynomene aspera* yields 'shola' of commerce which is extensively used for making hats. The seeds of *Abrus* are used as jewellers' weights.

SUBFAMILY 2. CAESALPINIEAE

Characters

Leaves—usually paripinnate or bipinnate. Flowers—in panicles, *slightly irregular* (but not papilionaceous), posterior petal smallest and innermost. Petals—5, *imbricate* in aestivation. Stamens—5+5, *or less* (due to abortion), *free*. Embryo—straight.

Fig. 564. Caesalpinieae (*Cassia fistula*).
A. Portion of a flowering shoot; B, Flower; C, The same after removal of calyx and corolla; D, Pistil; E, T.s. of ovary; F, Fruit: G, Magnified view of a portion of the same; H, Seed; I, Floral diagram.

KEY TO GENERA

(*a*) Leaves simple, 2-lobed .. .. .. *Bauhinia*.

(*b*) Leaflets paripinnate

Petals 5, anthers basifixed .. .. .. *Cassia*.

Calyx petaloid, scarlet, 4-lobed; corolla 0; sts. 8 .. *Saraca*.

Petals 0; calyx 5-lobed, green; stamens 10; leaflets 1-3, jugate .. .. *Hardwickia*.

Petals 3; stamens 3, monadelphous .. .. *Tamarindus*.

(*c*) Leaflets bipinnate

Trees, rusty tomentose shoots and rusty panicles of showy yellow flowers .. .. .. *Peltophorum*.

Trees, shrubs or prickly climbers

Calyx deeply cleft, the lowest lobe largest; petals orbicular, usually clawed .. .. *Caesalpinia*.

Calyx-lobes valvate and almost equal

Unarmed trees; flowers large, bright scarlet and variegated with yellow .. .. *Poinciana*.

Small armed trees; main leaf-rachis spinescent, pinnae with much-flattened rachis, small .. *Parkinsonia*.

Common plants

(1) Indian laburnum (*Cassia fistula* L.), a medium sized tree. (2) *C. occidentalis* L., *C. sophera* L. and *C. tora* L. are shrubs or undershrubs, commonly found in waste places. (3) Gold mohur tree (*Poinciana regia* Boj. = *Delonix regia* Raf.), often planted on roadsides and produces cream yellow flowers just before the rainy season. (4) Peacock flower (*Caesalpinia pulcherrima* Swartz.), also planted on roadsides and produces crimson flowers. (5) Tamarind (*Tamarindus indica* L.), a tall tree often planted for fruit. (6) Fever nut (*Caesalpinia bonducella* Fleming = *C. crista* L.), a hook climber. (7) The Ashoka tree (*Saraca indica* L.), often planted on roadsides and in gardens and has medicinal importance. (8) Camel's foot plants (*Bauhinia acuminata* L., *B. variegata* L., *B. purpurea* L.), small trees or woody climbers with emarginate leaves. (9) *Peltophorum ferrugineum* Benth. = *P. pterocarpum* Backer and *P. inerme* are trees with beautiful yellow flowers blossoming on the advent of summer, planted commonly in parks and along roadsides. (10) *Parkinsonia aculeata* L., a large shrub. (11) *Hardwickia pinnata* Roxb. = *Kingiodendron pinnata* Harms., a small tree.

Affinity

This subfamily is allied to Anacardiaceae but readily distinguished by having single carpel.

Fig. 565. Caesalpinieae (*Caesalpinia pulcherrima*).
A, Portion of a flowering shoot; B, Flower; C, Vertical section of the same; D, Stamen; E, Pistil; F, T.s. of ovary; G, Floral diagram.

Economic importance

The plants of this subfamily usually have purgative but non-poisonous properties. The tamarind is the most important plant. *Saraca* is of medicinal importance. *Bauhinia* yields good fibres.

SUBFAMILY 3. MIMOSAE

Characters

Leaves—usually bipinnate. Flowers—in spikes, regular, usually 4-merous, less frequently 5- or 3-merous. Petals—4, united or free, *valvate* in aestivation. Stamens—numerous, sometimes definite, exerted. Embryo—straight.

KEY TO GENERA

A. Stamens definite, 4, 5, 8 or generally 10

Marsh plants with flattened or angular stems, heads of flowers on long stalks; flowers hermaphrodite, male or neuter .. .. *Neptunia.*

Flowers in round heads, all flowers similar

(a) Leaf with one pair of pinnae .. .. *Xylia.*

(b) Woody climber with tendrils .. .. *Entada.*

(c) Erect unarmed tree with bipinnate leaves, fruit linear, falcate, seeds scarlet .. .. .. *Adenanthera.*

(d) Prickly trees or shrubs, pod turgid and spongy inside .. .. *Prosopis.*

(e) Herbs or shrubs with sensitive leaflets, pod flat and jointed .. .. *Mimosa.*

B. Stamens indefinite, much exserted

(a) Erect or climbing shrubs or trees armed with spiny stipules or recurved prickles; flowers white, yellow or purple in round heads or cylindrical spikes .. *Acacia.*

(b) Large unarmed trees, rarely climbing; leaves bipinnate, pinnae and leaflets several; flowers in round heads; stamens monadelphous; pods thin, strap-shaped, continuous within .. .. *Albizzia.*

(c) Tall trees; leaves bipinnate with pinnae one pair and leaflet one pair only, sometimes spinescent; stamens monadelphous; pod twisted .. .. *Pithecolobium.*

(d) Big trees; leaves bipinnate, leaflets many; stamens monadelphous; pod septate between seeds, valves spongy or fleshy .. .. .. *Enterolobium.*

Common plants

(1) Sensitive plant (*Mimosa pudica* L.), a common straggling herb. (2) The Babul or Gum tree (*Acacia arabica* Willd.), a small tree which yields gum. (3) Cutch tree (*Acacia catechu* Willd.), the wood of which on distillation produces 'cutch' of commerce. (4) *Acacia moniliformis* Griseb. commonly planted on roadsides and parks and bears phyllodes. (5) *Acacia recurva* also bears phyllodes, common in Darjeeling. (6) Silk flower (*Albizzia lebbeck* Benth.), commonly planted on roadsides. (7) *Entada scandens* Benth. = *E. phaseoloides* Merr., a woody climber with snake-like branches, the seeds of which are used for curling garments. (8) *Neptunia oleracea* Lour. and *N. plena* Benth., common water-weeds with sensitive leaves. (9) *Prosopis spicigera* L. (10) *Xylia dolabriformis* Benth., Iron wood tree of Burma. (11) Manila tamarind (*Pithecolobium dulce* Benth. = *Inga dulcis* Willd., a medium tree, common. (12) Rain tree (*Enterolobium saman* Prain = *Samanea saman* Merr.), an avenue tree. (13) Red wood (*Adenanthera pavonina* L.), a tree.

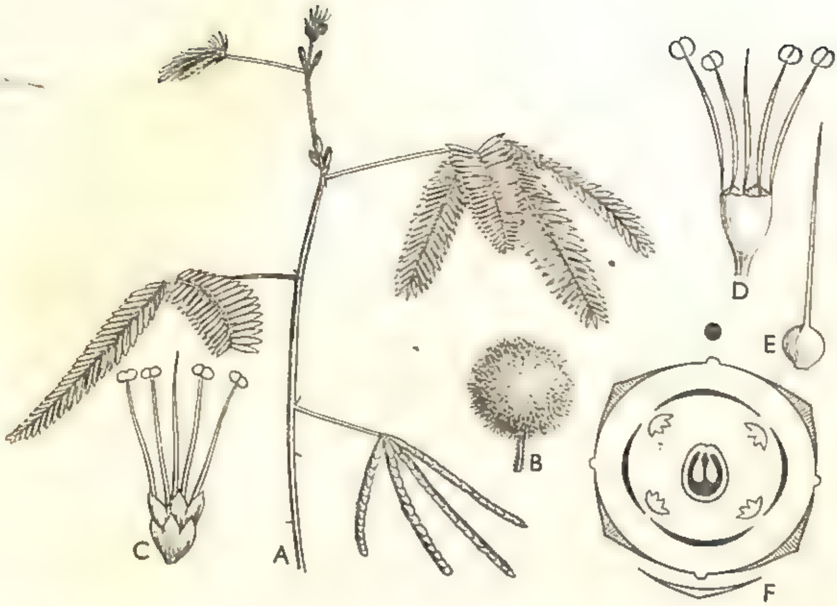


Fig. 566. Mimosae (*Mimosa pudica*).
A, Portion of a flowering shoot; B, Inflorescence; C, Flower; D, The same after removal of calyx and corolla; E, Pistil; F, Floral diagram

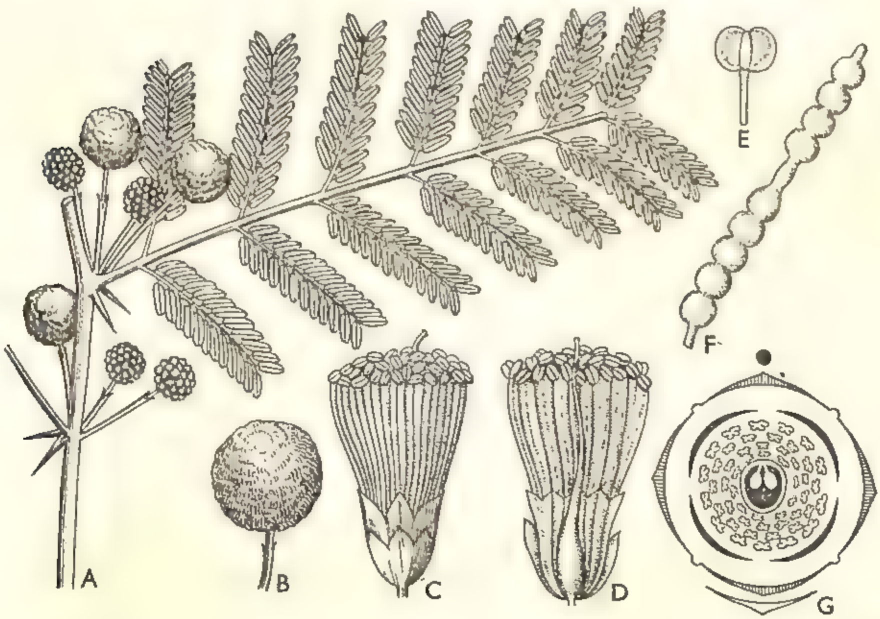


Fig. 567. Mimosae (*Acacia arabica*).
A, Portion of a flowering shoot; B, Inflorescence; C, Flower; D, V.s. of the same; E, Stamen; F, Fruit; G, Floral diagram.

Affinity

This subfamily is allied to Rosaceae but readily distinguished by the hypogynous stamens, position of odd sepal and nature of the fruit.

Economic importance

The plants of this subfamily possess mucilagenous juice and astringent properties. Gum tree and Cutch tree are the most important plants. *Xylia* is a valuable timber tree.

Comparison of Papilionaceae, Caesalpinieae and Mimosae

Papilionaceae	*Caesalpinieae*	*Mimosae*
1. Leaves—usually imparipinnate.	1. usually paripinnate.	1. bipinnate.
2. Flowers—very irregular, papilionaceous, odd petal biggest and outermost.	2. slightly irregular, odd petal smallest and innermost.	2. regular, 4-merous.
3. Aestivation—vexillary.	3. imbricate.	3. valvate.
4. Stamens—(9)+1 or (10).	4. 5+5 or less, free.	4. ∞ or definite.

ORDER 23. GERANIALES

Plants generally herbaceous, sometimes woody or lianes. Leaves alternate, sometimes opposite, exstipulate. Flowers bisexual, regular, more rarely zygomorphic, hypogynous, cyclic, pentamerous. Stamens obdiplostemonous. Carpels reduced to 3. Ovules pendulous with a ventral raphe. Styles often persistent. Seeds usually without endosperm.

According to Engler this Order consists of 6 suborders containing 20 families, viz., Geraniaceae, Oxalidaceae, Tropaeolaceae, Linaceae, Rutaceae, Meliaceae, Euphorbiaceae, etc. In Bentham and Hooker's system this Order is designated as cohort Geraniales which contains 7 families under the subclass Polypetalae. Rendle has included 7 families under this Order. Hutchinson has placed this Order under Archichlamydeae containing 7 families. This Order (20th Order) under Hutchinson's system consists of 7 families, viz., Linaceae, Geraniaceae, Oxalidaceae, Tropaeolaceae, Balsaminaceae, etc. Rutaceae has been put under the Order Rutales (55th Order), Meliaceae under the Order Meliales (51st Order) and Euphorbiaceae under the Order Euphorbiales (38th Order).

GERANIACEAE

General characters

Plants—herbs, often with fleshy stems. Leaves—alternate or opposite, compound but sometimes simple, usually palmiveined,

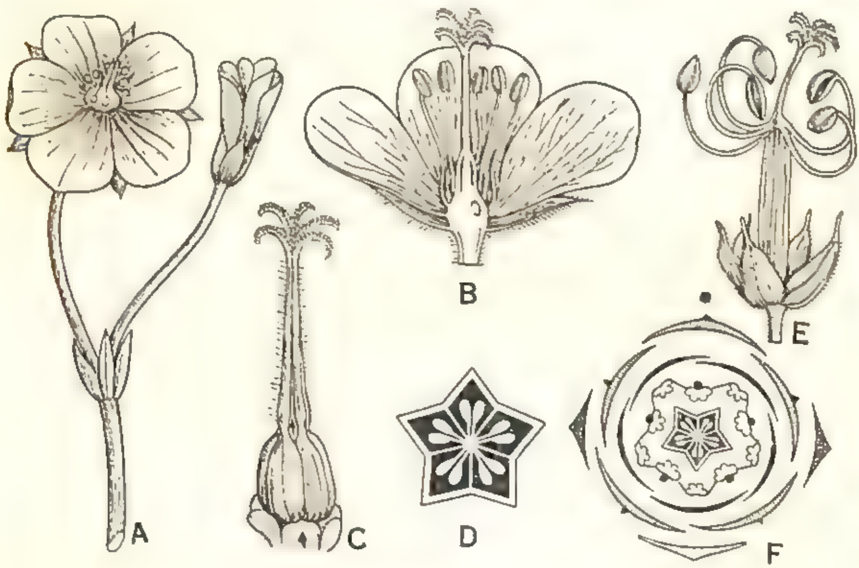


Fig. 568. Geraniaceae (*Geranium ocellatum*).
A, Portion of a flowering shoot; B, V.s. of a flower; C, Pistil; D, T.s. of ovary; E, Dehiscence of fruit; F, Floral diagram.

stipulate. Inflorescence—cymose. Flowers—regular, sometimes slightly irregular (e.g., *Pelargonium*), bisexual, hypogynous. Sepals—usually 5, imbricate. Petals—usually 5, with nectar glands alternating with them, imbricate. Stamens—*usually 10, obdiplostemonous*, rarely 15. Carpels—(3-5); ovary superior, beaked, 3-5-celled with 1 or 2 ovules in each; style 3-5, slender. Fruit—capsule, *dehiscing septicidally into 3-5 one-seeded beaked portions.* Seeds—exalbuminous with a straight or curved embryo.

Number and distribution

This family consists of 11 genera and about 850 species which are widely distributed in the temperate zone and in the hills.

Common plants

(1) *Geranium ocellatum* Camb., a small straggling herb producing

rose-coloured flowers with a purple 'eye', commonly found on the hills. (2) *G. nepalensis* Sw., a common herb found in Darjeeling. (3) *Pelargonium* sp., a garden plant, producing beautiful flowers.

Affinity

This family bears relationship with the members of Malvales in one hand in tendency of union of stamens and with Rutaceae on the other hand in obdiplostemony. It differs from Rutaceae in the absence of disc and oil-glands. Geraniaceae is characterized by the typically 5-merous flowers, obdiplostemonous stamens, septicidal dehiscence of the capsular fruit into 3-5 one-seeded beaked portions and exalbuminous seed.

Economic importance

This family is of little economic importance. Species of *Geranium*, *Pelargonium* and *Erodium* are ornamentals.

OXALIDACEAE

General characters

Plants—perennial herbs, sometimes trees (e.g., *Averrhoa*). Leaves—alternate, pinnately or palmately compound, exstipulate. Inflorescence—cymose. Flowers—regular, bisexual, hypogynous. Sepals—5, imbricate. Petals—5, twisted. Stamens—10 in 2 series, obdiplostemonous, (shortly monadelphous) *united at the base*. Carpels—(5); ovary superior, 5-celled with 1-many anatropous ovules in each; *style 5, free*. Fruit—capsule, *dehiscing along the dorsal suture*, or berry (e.g., *Averrhoa*). Seeds—sometimes *arillate*, albuminous with a straight embryo.

Number and distribution

This family consists of 7 genera and about 1,000 species which are chiefly distributed in the tropics.

Common plants

(1) Wood sorrel (*Oxalis corniculata* L.), a weed very common on roadsides and especially on cultivated lands. (2) *Biophytum sensitivum* DC., another common weed with sensitive leaves, chiefly found on cultivated lands. (3) Carambola (*Averrhoa carambola* L.),

a tree commonly planted for its fruits. (4) The Bilimbi (*A. bilimbi* L.), a small cultivated tree.

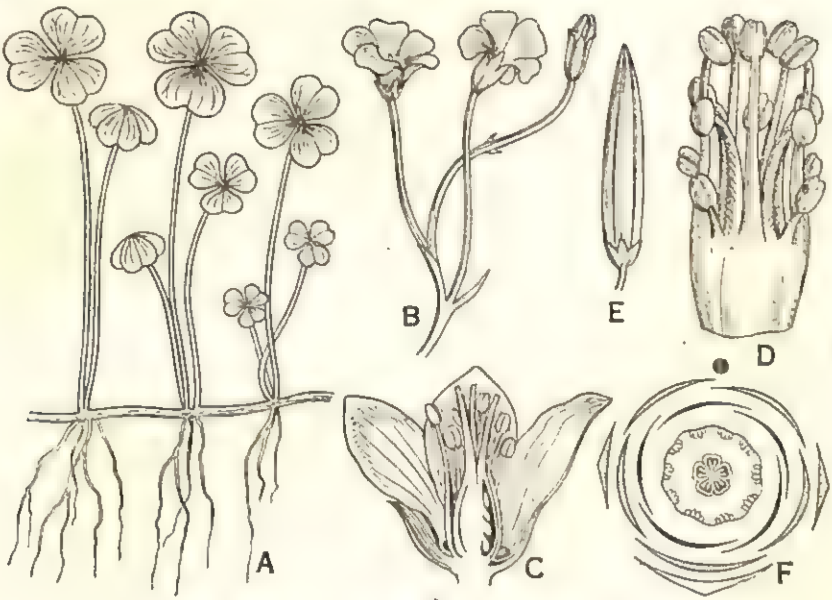


Fig. 569. Oxalidaceae (*Oxalis corniculata*).
A, Portion of a plant; B, Inflorescence; C, V.s. of a flower; D, Androecium; E, Fruit; F, Floral diagram.

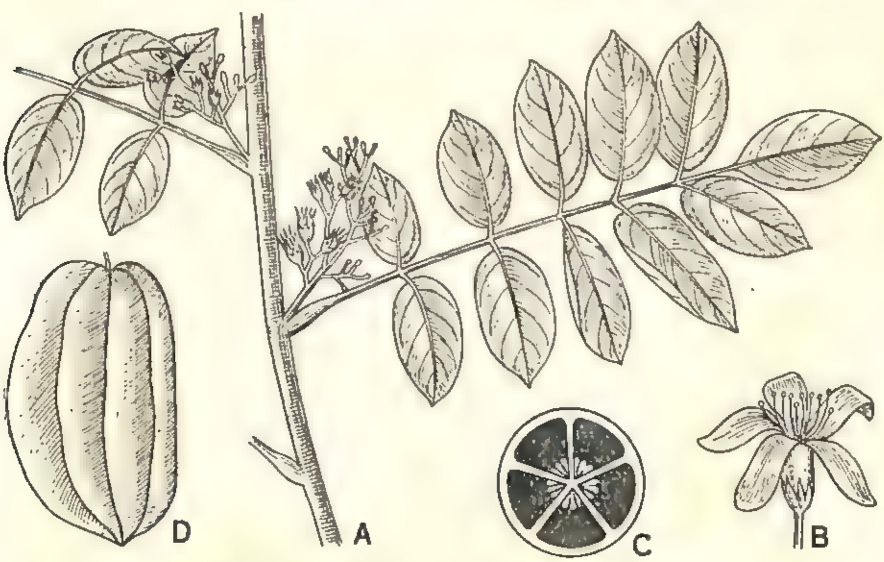


Fig. 570. Oxalidaceae (*Averrhoa carambola*).
A, Portion of a flowering shoot; B, Flower; C, T.s. of ovary; D, Fruit.

Affinity

This family is readily distinguished from other allied families by the palmately compound leaves, shortly monadelphous stamens, 5 free styles, 5-celled ovary, mode of dehiscence of fruit and arillate seeds.

Economic importance

This family is of little economic importance. The gooseberry-like fruits of Carambola (*Averrhoa*) are edible. A few species are ornamental.

KEY TO GENERA

(*a*) Fruits of loculicidally dehiscent capsules; stamens all perfect; herbs
- (*i*) Valves cohering with axis: leaves trifoliate . . *Oxalis.*
- (*ii*) Valves dehiscing from axis; leaves pinnately compound . . . . . . *Biophytum.*

(*b*) Fruits of indehiscent berries; often the stamens reduced to staminodes; leaves pinnate; trees . . . . *Averrhoa.*

TROPAEOLACEAE

General characters

Plants—mostly prostrate succulent herbs. Leaves—alternate, simple, *peltate*, sometimes lobed, exstipulate. Flowers—irregular, bisexual, hypogynous. Sepals—5, petaloid, *the dorsal one prolonged into a spur.* Petals—5, clawed, the upper 2 petals differ in shape from the lower 3 (usually smaller and situated in the opening of the spur), imbricate. Stamens—*8 in 2 whorls*, unequal. Carpels —(3);

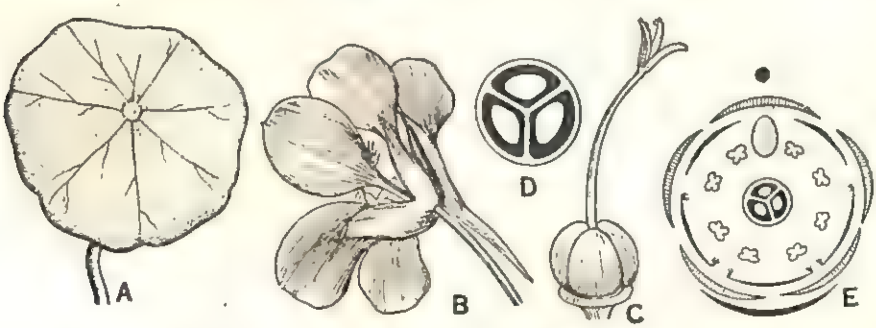


Fig. 571. Tropaeolaceae (*Tropaeolum majus*).
A, A single leaf; B, Flower; C, Pistil; D, T.s. of ovary; E, Floral diagram.

ovary superior, *3-celled* with 1 pendulous anatropous ovule in each; *style 1*; *stigma 3-fid*, linear. Fruit—a *3-seeded schizocarp*. Seeds—exalbuminous with a straight embryo.

Number and distribution

This family consists of 1 genus, *Tropaeolum* with about 60 species which are chiefly found on the hills.

Common plant

Garden Nasturtium (*Tropaeolum majus* L.), a common garden plant.

Affinity

This family is characterized by the peltate leaves, petaloid spurred sepal, 8 stamens in 2 whorls, 3 carpels, and the nature of the fruit.

Economic importance

This family is of very little economic importance. *Tropaeolum* is an ornamental plant.

LINACEAE

General characters

Plants—usually herbs, sometimes shrubs. Leaves—alternate or opposite, simple, entire, stipulate or exstipulate. Inflorescence—usually cymose (a dichasial cyme). Flowers—pentamerous, regular, bisexual, hypogynous. Sepals—5, free or slightly united at the base, imbricate. Petals—usually 5, often *clawed, twisted*. Stamens—5 or 10, the fertile stamens equal to the number of petals and antisepalous; *filaments united at the base* forming a ring, outside which nectar glands are present. Carpels—(5), antipetalous; ovary superior, usually 5-celled with 2 pendulous and anatropous ovules in the inner angle of each cell; styles free. Fruit—usually a capsule. Seed—with fleshy endosperm and a straight embryo.

Number and distribution

This family consists of 9 genera and about 200 species which are chiefly distributed in the temperate zone.

Common plants

(1) The Flax (*Linum usitatissimum* L.), commonly cultivated during the winter for the sake of oil and fibre. (2) *Rinwardtia*, a common garden ornamental.

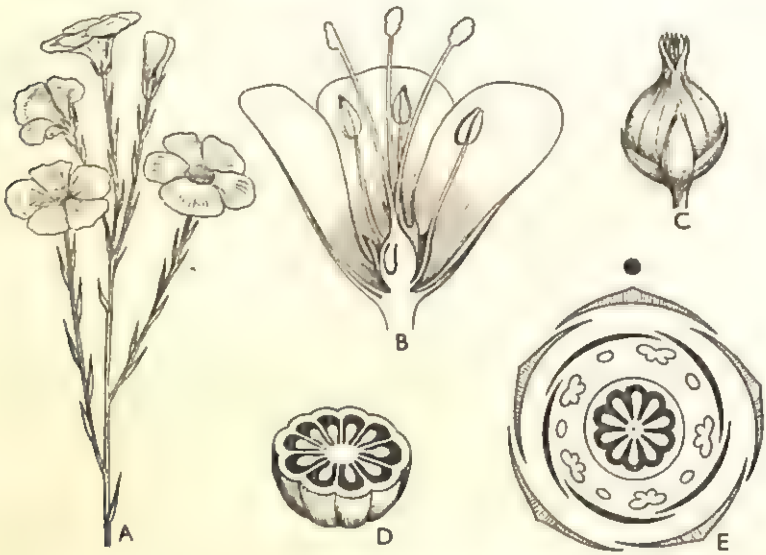


Fig. 572. Linaceae (*Linum usitatissimum*).
A, Portion of a flowering shoot; B, V.s. of a flower; C, Pistil; D, T.s. of ovary; E, Floral diagram.

Affinity

This family is readily distinguished from its allied families by the pentamerous flowers, clawed petals with twisted aestivation, short connate filaments and septicidally dehiscent capsule.

Economic importance

This family is economically important. *Linum usitatissimum* yields a kind of fibre which is used for preparing linen cloth, and also a kind of oil (linseed oil). A few species of *Linum* and *Rinwardtia* are ornamentals.

RUTACEAE

General characters

Plants—usually shrubs or trees, sometimes climbing, often provided with spines. Leaves—alternate or opposite, simple or

compound, smooth, mostly *gland-dotted*, exstipulate. Inflorescence—usually cymose. Flowers—regular (sometimes slightly irregular), usually bisexual (unisexual in *Zanthoxylum*), with an annular or cushion-like disc generally between or above the stamens. Sepals—4-5, free or united, *glandular*, imbricate. Petals—4-5 (but united

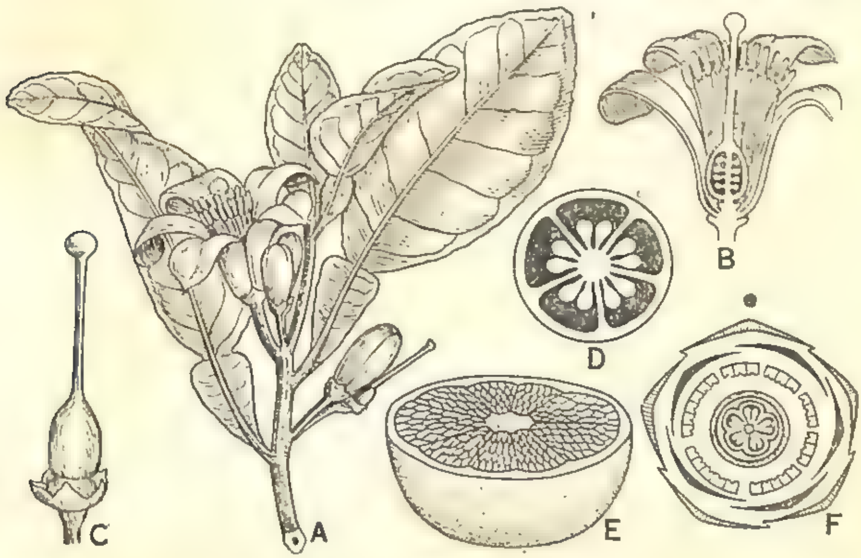


Fig. 573. Rutaceae (*Citrus aurantium*).
A, Portion of a flowering shoot; B, L.s. of a flower; C, Pistil;
D, T.s. of ovary; E, T.s. of fruit; F, Floral diagram.

in *Correa*), *glandular*, imbricate. Stamens—generally 8 or 10, *obdiplostemonous*, sometimes equal in number to the petals, or numerous (e.g., *Citrus* and *Aegle*), free or polyadelphous. Carpels—usually (4-5), sometimes free below and united above ; ovary superior, often 4-5-celled, usually deeply *lobed, situated on a disc;* style short; stigma capitate; placentation axile (but parietal in *Feronia*). Fruit—a *hesperidium* or *amphisarca*, sometimes a capsule. Seeds—with or without endosperm, and with a large straight or curved embryo.

Number and distribution

This family consists of about 140 genera and 1,300 species which are found in tropical and temperate climates.

Key to Genera

A. Fruit syncarpous; ovary entire; fls. polygamous
- (*a*) Stem unarmed
  - (*i*) Fls. usually 5-merous, leaves simple .. *Skimmia.*
  - (*ii*) Fls. 4-merous, leaves 1-3-foliate .. .. *Acronychia.*
- (*b*) Stem armed
  - Fls. 2-5-merous, 1-3-foliate .. .. *Toddalia.*

B. Fruit capsular; ovary deeply 2-5-lobed; fls. polygamous; leaves 3-foliate or imparipinnate .. .. *Zanthoxylum.*

C. Fruit berry; ovary entire; fls. bisexual; leaves compound
- (*a*) Ovules solitary or 2 in a loculus
  - (*i*) Petals 4-5, imbricate; ovary 2-5-celled; style very short; persistent ... . *Glycosmis.*
  - (*ii*) Petals 4-5, imbricate or valvate; stamens 8 or 10, inserted on a columnar disc, filaments free; anther linear-oblong; fls. large, axillary, solitary or fascicled .. .. .. *Paramignya.*
  - (*iii*) Petals 5; stamens 8 or 10; filaments dilated below; style deciduous .. .. .. *Clausena.*
  - (*iv*) Petals 5, imbricate; stamens 10, short and long filaments alternating; style deciduous, flattened below .. .. *Murraya.*
- (*b*) Ovules many in each loculus
  - (*v*) 20-60; leaves unifoliate .. .. .. *Citrus.*
  - (*vi*) Stamens 10-12; fruit large, many-seeded, woody rind .. .. *Feronia.*
  - (*vii*) Stamens 30-60; leaves 3-foliate; fruit large, globose; testa mucilagenous .. .. *Aegle.*

Common plants

(1) Orange (*Citrus aurantium* L. = *C. sinensis* Osbeck). (2) Lemon (*Citrus medica* L.). (3) Shaddock or Pumelo (*Citrus decumana* L. = *C. maxima* Merr.). (4) Wood apple (*Aegle marmelos* Correa), a tree cultivated throughout India for its fruits, which are of great medicinal value. (5) Elephant apple (*Feronia elephantum* Correa = *F. limonia* Swingle), a fruit tree. (6) Tooth-brush plant (*Glycosmis pentaphylla* Correa, a common shurb the twigs of which are used as tooth-brushes. (7) Orange jessamine (*Murraya exotica* L. = *M. paniculata* Jack.), a garden plant. (8) Curry-leaf plant (*Murraya koeningii* Spreng.), the leaves of which are extensively used as a condiment in South India. (9) Common rue (*Ruta graveolens* L.), a medicinal

plant. (10) *Atalantia monophylla* DC., a shrub often planted in gardens. (11) *Acronychia laurifolia* Bl. = *A. pedunculata* Miq., found in scrub jungles near Canning. (12) *Clausena heptaphylla* W. & A., generally found in village-shrubberies. (13) Prickly Ash (*Zanthoxylum trifoliatum* L. = *Acanthopanax trifoliatum* Merr.), a small tree armed with prickles. (14) *Paramignya citrifolia* Hook. f. and *P. angulata* Kurz. = *Merope angulata* Swingle, are thorny undershrubs common in Sundribans. (15) *Skimmia laureola* Hook. f., a glabrous shrub 3-5 ft. high, chiefly found in the hills. (16) *Toddália aculeata* Pers. = *T. asiatica* Lamk., a rambling prickly shrub.

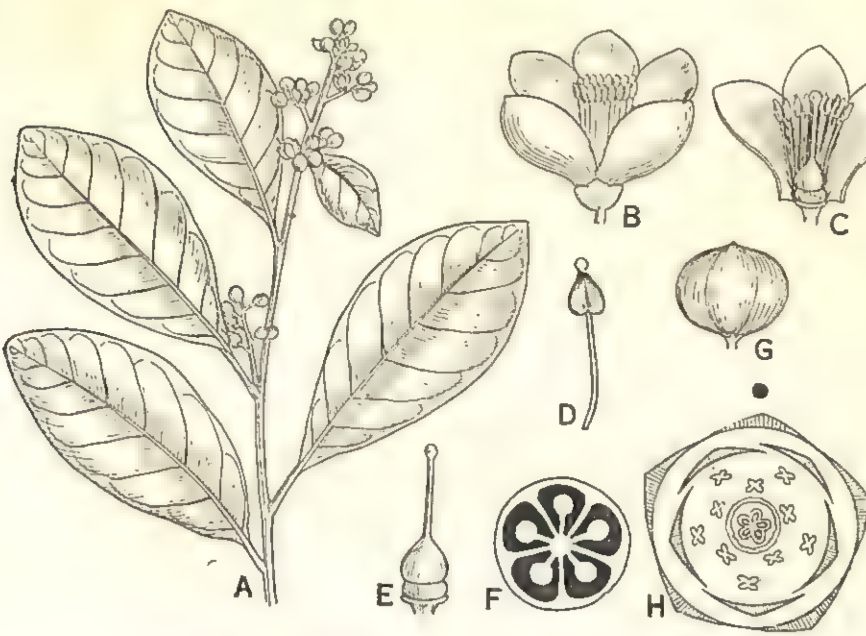


Fig. 574. Rutaceae (*Glycosmis pentaphylla*).
A, Portion of a flowering shoot; B, Flower; C, Corolla cut open showing androecium and gynoecium; D, Stamen; E, Pistil; F, T.s. of ovary; G, Fruit; H, Floral diagram.

Affinity

Engler placed Rutaceae under Geraniales, whereas Hutchinson places it under separate Order Rutales. This family resembles Meliaceae, Anacardiaceae and Sapindaceae in obdiplostemonous stamens, structure of leaf, heath-like habit, but readily distinguished from them by the presence of gland-dotted leaves, lobed ovary situated on a disc and the character of fruit. The family is also

closely related to Euphorbiaceae in the presence of ventral raphe of the ovule in some genera.

Economic importance

This family is fairly important economically. A number of genera produce edible fruits, such as, *Citrus*, *Feronia*, *Aegle*, etc. The leaves of *Murraya koeningii* are extensively used for making curry in South India. The bark of roots of *Toddalia* produces a yellow dye. *Ruta* is a medicinal plant. The young twigs of *Glycosmis* are used as tooth-brushes. Some plants are used as ornamentals, such as *Murraya*, *Zanthoxylum*, *Phellodendron*, etc.

MELIACEAE

General characters

Plants—trees or shrubs. Leaves—alternate, *pinnately compound*, exstipulate. Inflorescence—cymose panicle. Flowers—regular, bisexual, hypogynous, usually with an annular disc between stamens and petals. Sepals—(4-5), small, imbricate. Petals—4-5, twisted or imbricate, distinct or adnate to the staminal tube and then

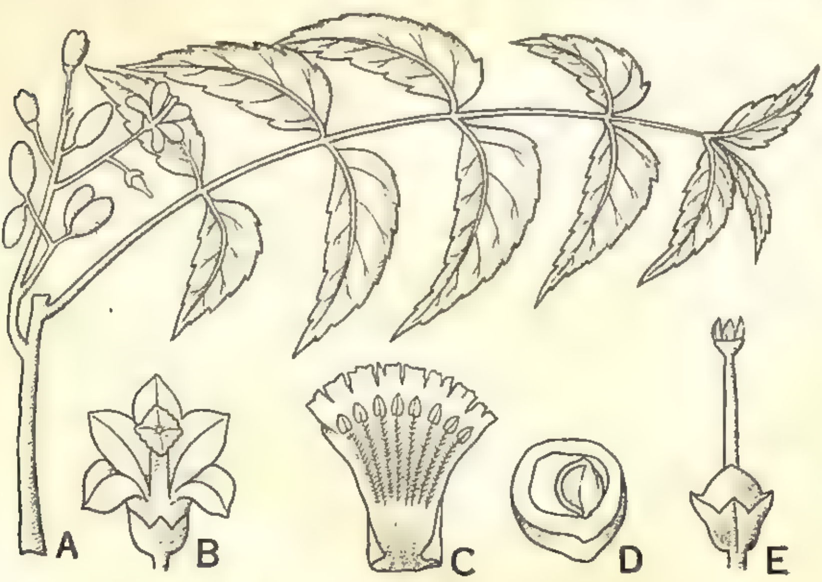


Fig. 575. Meliaceae (*Melia azadirachta*).
A, Portion of a flowering shoot; B, Flower; C, Staminal tube split open; D, T.s. of ovary; E, Pistil.

valvate. Stamens—8-10 in 2 whorls, mostly monadelphous (but free in *Cedrela*, and *Chloroxylon*), sometimes are converted into staminodes ; filaments *usually united*, rarely free; *anthers often sessile, inserted in the tube*. Carpels—(2-5); ovary superior, often 2-5-celled with mostly 2, rarely more (12 in *Swietenia*), ovules in each cell; stigma often *disciform* or *capitate*. Furit—capsule or berry, rarely drupe. Seeds—with or without endosperm, *often winged*.

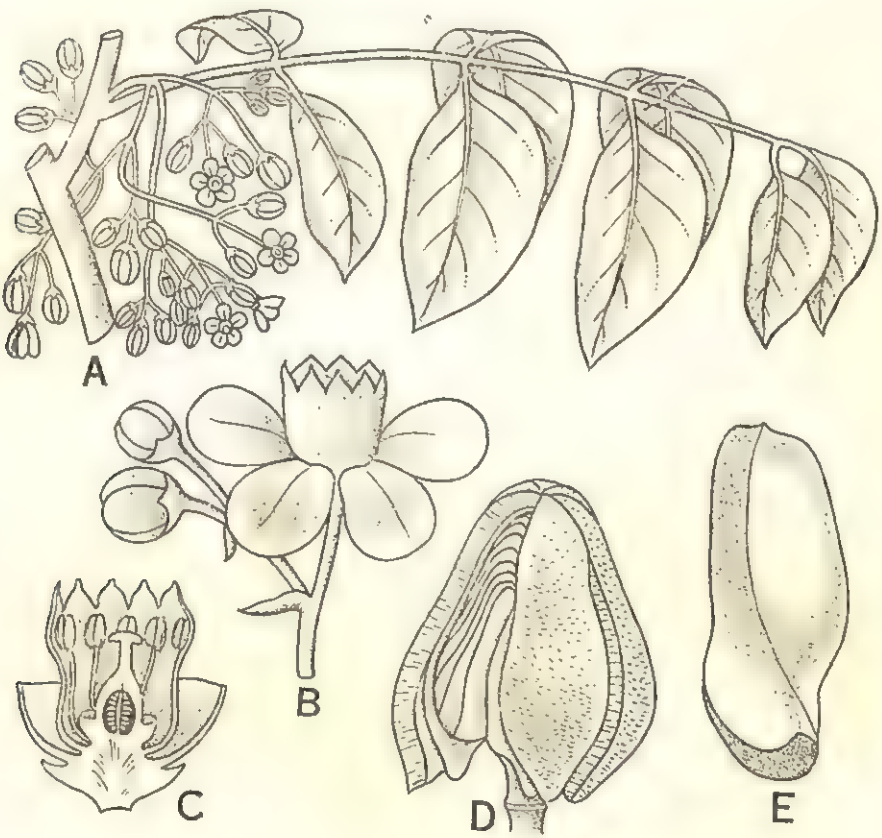


Fig. 576. Meliaceae (*Swietenia mahogani*).
A, Portion of a flowering shoot; B, Inflorescence; C, V.s. of a flower; D, Fruit; E, Seed.

Number and distribution

This family consists of 50 genera and about 800 species, widely distributed in the tropics.

KEY TO GENERA

A. Stamens connate in a tube

(a) Seeds not winged

(1) Leaflets serrate; ovules 1-2 in each cell; fls. elongated; calyx 5-partite; petals imbricate; style long; disc annular; ft. with a single 1-5-celled stone .. *Melia*.

(i) Fls. globose; calyx 5-toothed; petals valvate; style short; disc cup-shaped; fruit with 5 horny pyrenes .. .. *Cipadessa*.

(2) Leaflets entire

(ii) Ovules 1-2 in each cell; ft. berry, indehiscent, petals 5 .. .. *Aglaia*.

(iii) Ovules 1-2 in each cell; ft. 3-valved capsule; anthers included, filaments united; petals 3 .. *Amoora*.

(iv) Ovules 3-8 in each cell; ft. capsule; seeds large, without aril; petals 4 .. .. .. *Carapa*.

(b) Seeds winged

Petals spreading, oblong; staminal tube urceolate; seeds albuminous, wings only at the upper end .. *Swietenia*

B. Stamens free

Seeds winged; ovules 8-12 in each cell; ft. capsular.

(a) Petals oblong, erect; stamens 4-6 with alternating staminodes; ovary 5-celled; seed albuminous, winged at both ends or only below .. .. .. *Cedrela*.

(b) Petals clawed, spreading; stamens 10; ovary 3-celled, with 8 ovules in each cell; seeds exalbuminous, winged only above .. .. .. *Chloroxylon*.

Common plants

(1). Neem or Margosa tree (*Melia azedarachta* L. = *Azadirachta indica* A. Juss.), commonly found throughout India, possesses bitter taste in leaves and bark. (2) Persian lilac or Chinaberry tree (*Melia azedarach* L.), larger than the former one, cultivated. (3) Mahogany tree (*Swietenia mahogani* L.), a valuable timber tree; *S. microphylla* and *S. macrophylla* are commonly planted on roadsides. (4) Satin-wood (*Chloroxylon swietenia* DC.), another valuable timber tree. (5) Moulmein cedar or Toon wood (*Cedrela toona* Roxb.), a tall timber tree. (6) *Amoora cucullata* Roxb. and *A. rohituka* W. & A. = *Aphanamixis polystachya* Parker, commonly planted on roadsides. (7) *Aglaia roxburghiana* Miq. (8) *Carapa obovata* Bl., a small tree with large round fruit, chiefly found in the Sundribans. (9) *Cipadessa fruticosa* Bl., a much-branched shrub.

Affinity

This family is allied to Rutaceae and Sapindaceae but readily distinguished from them by the monadelphous stamen, disciform or capitate stigma, and winged seeds. It is distinguished from Burseraceae by the absence of resin ducts.

Economic importance

This family is of little economic importance. *Melia* is a medicinal plant. Many are valuable timber trees e.g., *Swietenia, Chloroxylon* and *Cedrela*.

EUPHORBIACEAE

General characters

Plants—minute herbs to huge trees, monoecious or dioecious, often with milky latex. Leaves—usually alternate, may be opposite or whorled (in many cases the upper ones are opposite while lower ones alternate), simple, entire or palmately lobed, very rarely compound (e.g., species of *Bischofia*), while in others reduced to spines. Inflorescence—various, raceme-cyme, sometimes cyathium or a dichotomous cyme, subtended by involucral or brightly coloured bracts. Flowers—usually small, incomplete, *unisexual*, regular or slightly irregular. Perianth—pentamerous, often small, green, sometimes absent; rarely differentiated into calyx and corolla (e.g., *Jatropha*), valvate or imbricate. Stamens—in male flowers as many as the perianth leaves or double as many, or very numerous or few or one (e.g., *Euphorbia*); filaments free or united, rarely branched (e.g., *Ricinus*); anthers 2-celled; rudiments of ovary present or absent. Carpels—in female flowers (3); ovary superior, *generally 3-celled* with axile placentation, each cell containing *1 or 2 pendulous* anatropous ovules with ventral raphe; micropyle carunculate, staminodes present or absent; styles 3, free or united at the base, each often 2-lobed; stigmas 3 or 6. Fruit—schizocarp-capsule (*regma*), sometimes drupe. Seeds—albuminous, *carunculate*. Embryo—straight or bent.

Number and distribution

This family consisting of 283 genera and about 7,300 species which are chiefly found in the tropics, shows a considerable variety

of habit from mesophytic to xerophytic tendencies, the latter being much more common to dry rocky soils of India.

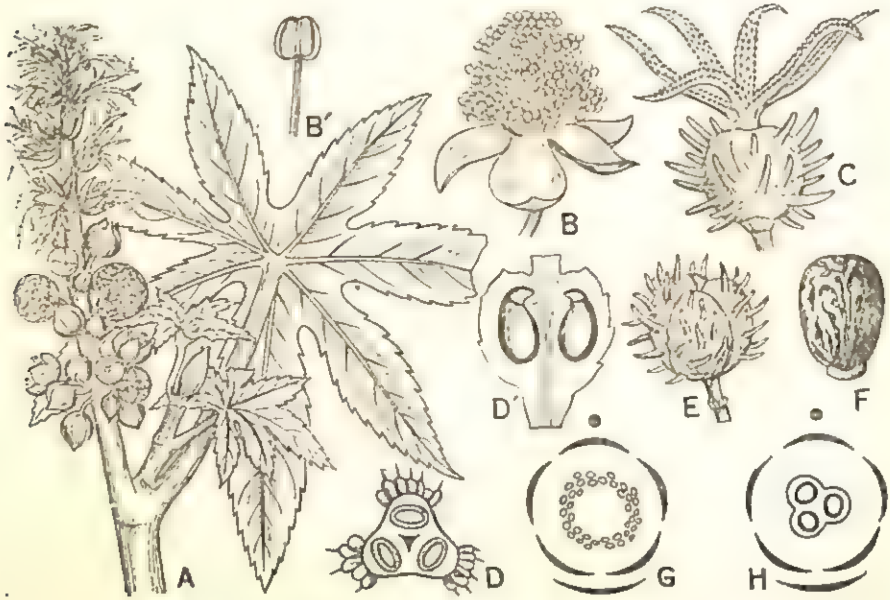


Fig. 577. Euphorbiaceae (*Ricinus communis*).
A, Portion of a flowering shoot; B, Staminate flower; B′, Stamen; C, Pistillate flower; D, T.s. of ovary; D′, L.s. of the same; E, Fruit; F, Seed; G, Floral diagram of a staminate flower; H, The same of a pistillate flower.

Key to Genera

A. Flowers aggregate, monoecious (in cyathium)—

Involucre regular, each segment alternates with free gland; ovary 3-locular with 8 ovules in each .. .. *Euphorbia.*

Involucre slipper-shaped, drawn into a spur, glandular within .. .. *Pedilanthus.*

Involucre urn-shaped, single stamen .. .. *Poincettia.*

B. Flowers separate, monoecious, not reduced to single stamens and pistils—

(*a*) Cells of ovary 2-ovuled

Herbs, shrubs or trees; leaves distichous, alternate; branchlets often resembling pinnate leaves; petals *O;* disc of distinct scales .. .. .. *Phyllanthus.*

(*b*) Cells of ovary 1-ovuled; flowers in spikes or racemes; sepals imbricate; petals present in male fls.

Petals present or obsolete in femle flowers; disc of 4-6 glands opposite the sepals .. .. *Croton.*

Petals absent in female flowers: disc of 5-6 glands alternate with petals: garden shrubs with ornamental leaves .. .. *Codiaeum.*

(*c*) Cells of ovary 1-ovuled; flowers in spikes or racemes; calyx segments 5, valvate; petals 5 in male flowers, disc of 5 glands alternate with petals: herbs or undershrubs; leaves sinuate, toothed; wavy or plicate, 2-glandular at the base .. .. *Chrozophora.*

(*i*) Herbs or shrubs; leaves toothed or crenate, rarely entire; flowers in racemes or spikes, male flowers without bracts, female flowers with accrescent leafy bracts; sepals 4; petals *O* .. .. *Acalypha.*

(*ii*) Tall annuals, sometimes shrubs; leaves large, broad, palmately lobed, lobes 7 or more, serrate; calyx of 3-5 valvate segments; petals of male and female flowers *O;* stamens numerous, filaments united, branched; flowers in terminal panicles *Ricinus.*

(*iii*) A climbing herb with hispid stinging hairs; male sepals valvate and female sepals imbricate .. *Tragia.*

(*iv*) Trees and shrubs; leaves serrate or toothed; flowers in terminal spikes or racemes ; calyx of 2-3 valvate segments; stamens 2 or 3; petals *O* in male and female flowers .. .. *Sapium.*

(*v*) Herbs, shrubs or trees, often glandular or prickly; leaves often lobed; sepals and petals 5; stamens many, filaments of inner series united; central flowers in the cyme or in forks usually female, flowers scarlet, purple or yellow .. .. *Jatropha.*

C. Fls. dioecious:

Trees with compound leaves .. .. .. *Bischofia*

Plants with simple leaves—

(*i*) Large shrubs or trees; fls. axillary or leaf-opposed clusters; petals *O;* stamens 10-60; pistillode absent; disc obsolete; fruit 3-4-gonous or 2-4-lobed fleshy capsule; leaves alternate .. *Gelonium.*

(*ii*) Trees; male flowers clustered, female sub-solitary; calyx 3-6-lobed; stamens 2-4; style short, dilated into broad fleshy arms; fruit a one-celled drupe *Putranjiva.*

(*iii*) Shrubs or trees flowers in spikes or racemes; calyx 3-8-toothed; stamens 2-5; fruit a small drupe crowned with terminal stigmas .. .. *Antidesma.*

(*iv*) Trees; fls. in racemes; stamens 4-8, filaments short; ovary 2-3-celled; fruit fleshy capsule; testa with a thick fleshy covering .. .. *Baccaurea.*

(v) Trees or shrubs: leaves opposite or alternate: fls. minute, apetalous in spike or panicle; stamens numerous, anther cells 2, globose, adnate to the broad connective: fruit capsule: female fls. often with disc .. .. *Mallotus*.

Fig. 578. Euphorbiaceae (*Croton sparciflorus*).
A, Portion of a flowering shoot; B, Staminate flower; C, Pistillate flower; D, T.s. of ovary; E, Floral diagram of a staminate flower; F, The same of a pistillate flower.

(vi) Trees, with opposite leaves; male flowers in raceme, female flowers few, disc never present; fruit drupe; gall structures commonly occur in leaves .. .. *Trewia*.

(vii) Shrubs or small trees; leaves alternate or opposite; flowers rarely monoecious; petals in male and female flowers O, disc O; fruit a capsule of 3 cocci separating from the columella with twisted valves; common in salt areas of Sundribans .. *Excoecaria*.

Range of floral structures

This family has a wide range in floral structures and organization. The flowers may be diplochlamydeous, bisexual and pentamerous. The perianth leaves are free or connate. Number of sepals and

Fig. 579. Euphorbiaceae (*Poincettia pulcherrima*).
A. Portion of a flowering shoot; B, Inflorescence; C, T.s. of the same; D, Staminate flower; E, Pistillate flower; F, T.s. of ovary; C, Floral diagram of cyathium.

petals varies in different cases which may be more or less than 5, as in *Phyllanthus* sp. Sepals and petals range from 4-6. Regarding the number of stamens and their disposition there are extraordinary variation. The stamens may be single, as in all members

of the genus *Euphorbia*, or may be 3, 10 to several hundred, as in *Trewia*, *Ricinus*, etc. In many cases, about 20-25 per cent of the total genera, the stamens are monadelphous, e.g., *Wielandia*, *Phyllanthus*, *Jatropha*, etc. In some cases, out of 10-15 stamens (arranged in 2 or 3 whorls) outer 5 stamens are free and rest inner are monadelphous, e.g., *Chrozophora*. Sometimes androphore and gynophore are present, e.g., *Bridelia*. Stamens may be polyadelphous, as in *Lesoecocous*, *Ricinus*. Male and female flowers are heteromorphic, e.g., *Aposora*.

Fig. 580. Euphorbiaceae (*Chrozophora plicata*).
A, Portion of a flowering shoot; B, Staminate flower; C, The same split open; D, Pistillate flower; E, Fruit.

Regarding the carpels, there are numerous variations, e.g., carpels 2-15 in *Glochidion*, and some species of *Phyllanthus*. In *Artilesma*, owing to the abortion of other carpels the ovary is 1-celled. In *Baccaurea* the ovary is 2-5-celled. In many genera, e.g., *Pridelia*, either pistillode or staminode is present.

Common plants

(1) Castor-oil plant or Castor bean (*Ricinus communis* L.), a shrub commonly cultivated for the seeds from which castor oil is extracted.

(2) Physic-nut (*Jatropha curcas* L.), and *J. gossypifolia* L. and *J. glandulifera* Roxb., are common shrubs on roadsides or hedges. (3) *Jatropha multifida* L., a common garden plant with red flowers. (4) *Jatropha thomsoni*, a favourite garden plant. (5) *Euphorbia pulcherrima* Willd. = *Poincettia pulcherrima* R. Garh., a common garden plant with vermillion-coloured leafy bracts. (6) *E. antiquorum* L., another common hedge plant with fleshy three-angled stem. (7) *Pedilanthus tithymaloides* Poit., a common hedge plant. (8) *Croton sparciflorus* Morung. = *C. bonplandianum* Baill., a common weed of waste places. (9) *Euphorbia nerifolia* L., a shrub with obovate

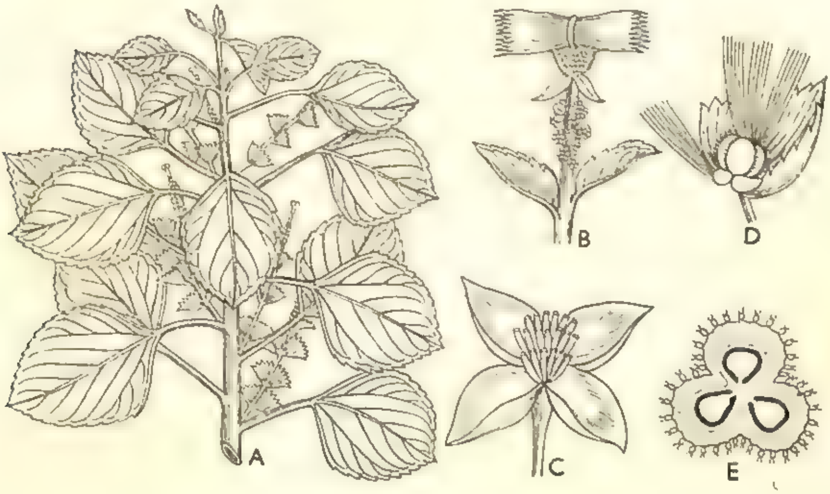


Fig. 581. Euphorbiaceae (*Acalypha indica*).
A, Portion of a flowering shoot; B. Inflorescence; C. Staminate flower; D. Pistillate flower; E, T.s. of ovary.

leaves; Milk hedge (*E. tirucauli* L.) is cultivated as a hedge plant. (10) *Euphorbia thymifolia* Burm. = *E. nivulla* L., *E. pilulifera* L. = *E. hirta* L. and *E. macrophylla* Heyne, are very small prostrate weeds of pathways. (11) *Phyllanthus embelica* L. = *Embelica officinalis* Gaertn. and *P. distichus* Muell. = *Cicca acida* Merr. are common fruit trees. (12) *Phyllanthus niruri* L., and *P. simplex* Retz., common weeds. (13) *Trewia nudiflora* L., a common deciduous tree. (14) Indian Stinging Nettle (*Tragia involucrata* L.), a common weed with stinging hairs. (15) *Acalypha indica* L. and *A. fallax* Muell.-Arg., are common weeds of waste places with a green bract enclosing the female flowers. (16) *Acalypha hispida*, a favourite garden plant with long pendulous

catkins. (17) Croton-oil plant (*Croton tiglium* L.). (18) *Chrozophora plicata* Hook. f., a common weed. (19) *Baccaurea sapida* Muell., commonly found in Eastern Pakistan which produces delicious edible fruits like mangosteen. (20) *Excoecaria agallocha* L., commonly found in Sundribans whose latex produces blisters on skin. (21) Monkey-face tree (*Mallotus philippinensis* Muell.-Arg.), a tree known for its anthelmentic, vermifugal and purgative properties. (22) Manihot (*Manihot utilissima* Pohl. = *M. esculenta* Crantz., produces the cassava

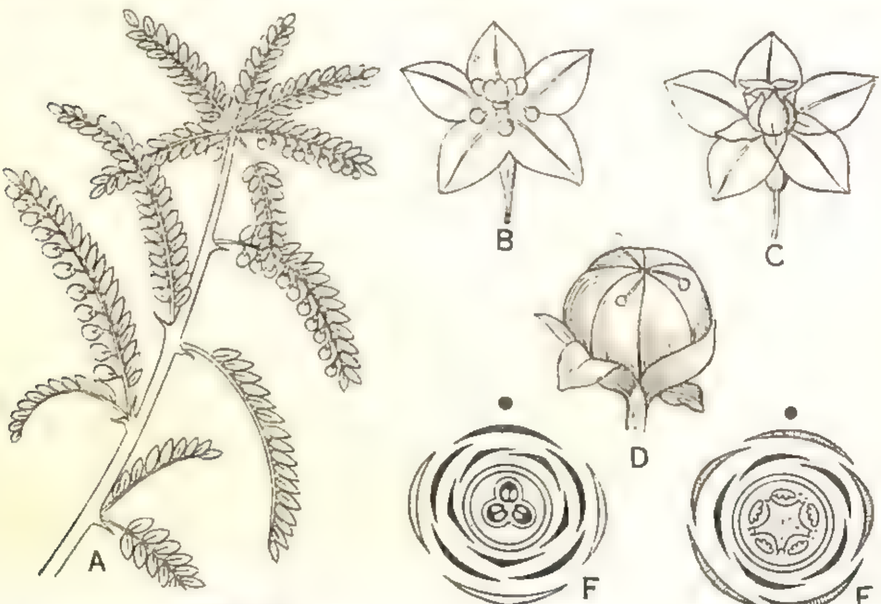


Fig. 582. Euphorbiaceae (*Phyllanthus niruri*).
A, Portion of a flowering shoot; B, Staminate flower; C, Pistillate flower; D, Fruit; E, Floral diagram of staminate flower; F, The same of pistillate flower.

starch. (23) Para-rubber (*Hevea brasiliensis*), a rubber-producing plant. (24) *Bischofia javanica* Bl. and *Putranjiva roxburghii* Wall., are common avenue trees. (25) *Antidesma ghesembilla* Gaertn., a common shrub of villages. (26) Garden croton (*Codiaeum variegatum* Bl.). (27) *Sapium indicum* Willd. found in the Sundribans. (28) *Sapium sebiferum* Roxb., very common. (29) *Gelonium multiflorum* A. Juss., very common.

Affinity

This famly is cleosly allied to Malvales, particularly Steruclia-ceae, owing to the presence of monadelphous stamens in about

25 per cent of the total genera, the presence of pistillode and staminode and occasionally androphore and gynophore and in nature of embryo. The family might have been evolved from the ancestor of Malvales by suppression of inner whorl of perianth and abortion of one of the stamens or carpels. Bentham and Hooker placed the

Fig. 583. Euphorbiaceae (*Trewia nudiflora*).
A, Portion of a staminate shoot; B, Portion of a pistillate shoot; C, Staminate flower; D, Stamen; E, Pistillate flower; F, T.s. of ovary.

family in series Unisexuales under the subclass Monochlamydeae. Wettstein is of opinion that it is primitive due to unisexual monochlamydeous flower. Euphorbiaceae is readily distinguished by the milky latex, unisexual flowers, 3-carpellate and 3-celled ovary with 1 or 2 pendulous ovules having ventral raphe in each cell, and carunculate seed.

Economic importance

This family is of great economic importance. Rubber is obtained from *Hevea braziliensis* and *Manihot glaziovii*. A kind of starch and Brazilian arrowroot are obtained from *Manihot utilissima*. Castor oil is obtained from *Ricinus communis* and tung oil from *Aleurites fordii*. A kind of oil and fat is obtained from *Sapium sebiferum*. Some plants are used as ornamentals, such as *Codiaeum*, *Jatropha*, *Euphorbia*, *Poincettia*, etc.

ORDER 24. SAPINDALES

Plants usually woody. Flowers bisexual, often unisexual by reduction, regular but frequently irregular, hypogynous with tendency to perigyny. Hypogynous disc present. Stamens diplostemonous. oil glands absent. Ovules pendulous with dorsal raphe present. Fruit various, often one-seeded. Seeds exalbuminous.

According to Engler this Order consists of 11 suborders containing 21 families, viz., Anacardiaceae, Sapindaceae, Balsaminaceae, etc. Bentham and Hooker have placed the first two families in the cohort Sapindales under the subclass Polypetalae, while Balsaminaceae was included under Geraniaceae. In Hutchinson's system the Order (57th Order) consists of 9 families, viz., Sapindaceae, Anacardiaceae, etc., but Balsaminaceae has been removed from this Order and placed under the Order Geraniales.

ANACARDIACEAE

General characters

Plants—trees or shrubs, *often with resinous juice.* Leaves—alternate (but opposite in *Dobinea*), usually *simple* (but compound in *Spondias*, *Odina* and *Rhus*), exstipulate. Inflorescence—panicle, terminal or axillary. Flowers—small, regular, bisexual but often unisexual by reduction, with more or less *cup-shaped glandular disc between the stamens.* Sepals—(3-5), united at the base. Petals—3-5, free. Stamens—10 in 2 whorls, free, usually fewer (1 in *Anacardium*, 5 in *Rhus*) arising from the rim of an intrastaminal disc. Carpels—usually (3) but functionally 1; ovary 1-celled (rarely 5-celled e.g., *Spondias* and *Buchanania*), *ovule solitary, anatropous with a dorsal raphe;* style usually 1, eccentric. Fruit—usually a *drupe*,

sometimes nut. Seed—exalbuminous. Embryo—curved, with fleshy cotyledons.

Number and distribution

This family consists of 73 genera and about 600 species which are chiefly found in the tropics.

Fig. 584. Anacardiaceae (*Mangifera indica*).
A, Portion of a flowering shoot; B, Flower; C, V.s. of the same; D, Fruit; E, Floral diagram.

Key to Genera

A. Ovary 1- or 2-celled

(*a*) Leaves alternate; perianth not fleshy

(*i*) Calyx 4-5; corolla 4-6; leaf pinnate .. *Rhus.*

(*ii*) Calyx 4-5; stamens 5 (usually 1 fertile); style 1, filiform; leaf simple .. .. .. *Mangifera.*

(*iii*) Calyx 5; stamens 8-10 (usually with staminodes); style 1, filiform; torus striated; leaf simple .. *Anacardium.*

(*iv*) Calyx 3-5; stamens 10; carpels 5 or 6 (all but one sterile), leaf simple .. .. *Buchanania.*

(b) Leaves 3-foliate or pinnate: petals imbricate; stamens 8-10; styles 3-4; fls. polygamous .. .. *Odina.*

(c) Leaves simple

Petals imbricate: stamens 5: styles 3; fr. drupe on an enlarged peduncle .. .. .. *Semecarpus.*

B. Ovary 2-5-celled: ovules pendulous from the top: leaves compound: fls. polygamous; stamens 8-10; styles 4-5, free above .. .. *Spondias.*

Fig. 585. Anacardiaceae (*Anacardium occidentale*). A, Portion of a flowering shoot; B, Flower; C, The same after removal of calyx and corolla; D, V.s. of same; E, Fruit.

Range of floral structures

This family also exhibits a little variation in the floral parts.

The flowers are generally bisexual but sometimes unisexual by the obliteration of stamens or pistils.

The members of this family show wide variation in the form of floral axis. The floral disc is generally convex in form. In some cases a cup-like floral disc (receptacle) is found between stamens and pistil, e.g., *Rhus*, or the floral axis becomes occasionally lengthened or thickened, as in *Mangifera indica.*

The variation in the number of stamens is also noticeable. In the genus *Buchanania*, all the 10 stamens are fertile; *Rhus* has only

5 stamens; 10-7 stamens occur in *Anacardium* but 1 stamen is found to be fertile; there are 5 antisepalous stamens in *Mangifera* but ultimately 1 stamen becomes fertile.

The variation in the number of carpels and chambers of ovary is also manifested in many genera of this family. The number of carpels is 5 in *Buchanania*, where only one ovule develops into seed on maturation. In the genera, such as, *Mangifera* and *Anacardium* there occur 1 carpel in each. Ovary is usually 1-celled, rarely 5-celled, as in *Buchanania*.

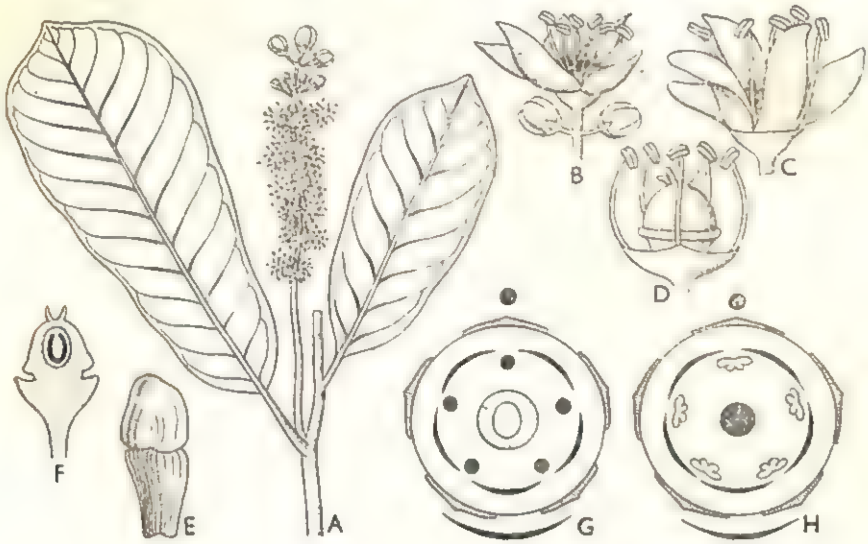


Fig. 586. Anacardiaceae (*Semecarpus anacardium*).
A, Portion of a flowering shoot; B, A part of an inflorescence; C, A bisexual flower; D, The same after removal of sepals and petals; E, Fruit; F, L.s. of ovary; G-H, Floral diagrams of pistillate and staminate flowers respectively.

Common plants

(1) Mango (*Mangifera indica* L.), a common fruit tree found throughout India. (2) Cashew-nut (*Anacardium occidentale* L.), abundantly found along the coast of Bay of Bengal and remarkable for the fleshy enlargement of the peduncle supporting the kidney-shaped nut. (3) Marking nut (*Semecarpus anacardium* L.), found in villages with a fleshy enlargement of the peduncle bearing a roundish nut, the juice of which is chiefly used by the washerman for marking clothes. (4) Hog-plum (*Spondias dulce* Willd.). (5) Indian

Hog-plum (*Spondias mangifera* Willd. = *S. pinnata* Kurz.). (6) Indian Ash tree (*Odina woodier* Roxb. = *Lannea coromandelica* Merr.) yields copious gummy substance. (7) Sumac (*Rhus succedanea* L.), commonly found in Assam. (8) *Buchannia latifolia* Roxb. *B. lanzan* Spreng., a medium-sized tree. (9) Green almond (*Pistacia vera* L.) yields pistacia nuts.

Affinity

This family is allied to Sapindaceae but readily distinguished by the presence of resinous juice and intrastaminal disc, the usually 1-celled ovary and drupaceous fruit. It is considered that Sapindaceae has been derived from Rutaceae. According to Hutchinson it is now-a-days regarded as one of the more advanced members of the Order Sapindales.

Economic importance

This family is economically important. Some plants yield edible nuts of pistachio (*Pistacia vera*), and cashew (*Anacardium occidentale*). The seeds of *Buchanania latifolia* are nutritious and palatable when roasted and are used as a substitute for almonds. The most delicious fruit is obtained from *Mangifera indica*. Commercial tannic acid is derived from *Schinopsis* sp. *Rhus* is a medicinal plant. Resins, oils and lacquers are obtained from *Toxicodendron vernicifera* and *Pistacia lentiscus*. A few species are ornamentals.

SAPINDACEAE

General characters

Plants—trees or shrubs, sometimes tendril-climbers (e.g., *Cardiospermum*). Leaves—alternate, usually pinnately *compound*, exstipulate (but stipulate in climbing species). Inflorescence—*panicle* (excepting *Cardiospermum*, which has a dichotomous cyme). Flowers—small, regular or irregular, bi- or uni-sexual, apparently polygamous, with an annular or oblique *disc between the petals and stamens*. Sepals—5, generally free, but in regular flowers frequently 4 by the union of the third and the fifth, imbricate. Petals—5, but become 4 by suppression of a petal, rarely 0, free, *often provided with scales*, imbricate. Stamens—usually 8, free, inserted inside the disc or outside it or on it. Carpels—(3); ovary 3-celled, lobed or entire, with one

ascending ovule with a ventral raphe in each cell; style terminal. Fruit—dry (a nut or capsule), or fleshy (berry or drupe). Seed—exalbuminous, *often with an aril.* Embryo—curved or convoluted.

Fig. 587. Sapindaceae (*Cardiospemum halicacabum*).
A, Portion of a flowering shoot; B, Flower; C, The same after removal of corolla; D, Stamens; E, T.s. of ovary; F, Fruit; G, Floral diagram.

Number and distribution

This family consists of 130 genera and about 1100 species which are chiefly found in the tropics.

KEY TO GENERA

A. Irregular flowers; disc one-sided

(*a*) Fruit capsule, inflated; ovule solitary; inflorescence axis turns into tendril .. .. .. *Cardiospermum.*

(*b*) Fruit divides into 1 or 3 indehiscent oblong lobes; leaves pinnate .. .. *Erioglossum.*

(*c*) Fruit indehiscent

(*i*) Leaves digitately 3- or 1-foliate .. .. *Allophyllus.*

(*ii*) Leaves paripinnate; stamens outside the disc .. *Aphania.*

B. Regular flowers; disc central

(*d*) Fruit deeply divided into 1-3 lobes

(*iii*) Sepals 4-5, imbricate; ft. smooth; seed without aril; stamens usually 8 .. .. *Sapindus.*

(iv) Sepals 4-5, valvate: stamens 6-8, inserted within the disc: ft. dry: seeds arillate .. .. *Schleichera.*

(v) Sepals valvate: petals small or 0: stamens 6-8 or 10, inserted within the disc: ft. muricated or tubercled, seeds embedded in pulpy edible aril: fls. usually panicled .. .. .. *Nephelium.*

(vi) Sepals 2-5, imbricate or valvate: petals 0: stamens usually 8, inserted on the outer side of the disc: ft. capsule, 2-6-seeded: seeds without aril .. *Dodonaea.*

Fig. 588. Sapindaceae (*Sapindus trifoliatus*).
A, Portions of twigs with flowers and fruits; B, V.s. of a staminate flower; C, L.s. of a pistillate flower; D, T.s. of ovary; E, T.s. of a fruit; F, Floral diagram of staminate flower; G, The same of pistillate flower.

Range of floral structures

Variation in floral structures is also noted in this family. Both regular and zygomorphic flowers occur. *Sapindus*, *Nephelium* and *Litchi* have regular flowers; irregular flowers occur in *Cardiospermum*, *Erioglossum* and *Allophyllus*.

Flowers may be unisexual or bisexual. Bisexual and staminate flowers are found in some species, while bisexual and pistillate flowers occur in others.

Variation in the number of petals also occurs. Petals are found to be absent in some genera, such as, *Dodonaea*, *Schleichera*, etc.

The number of stamens also differs in different genera. Stamens are usually 8. The typical pentamerous genus *Turpinia* possesses 5

stamens. Multiple stamens are noted in the African genus *Deinbollia.*

The number of style in most cases is one, but it varies from 2-4; ovary 3-locular, but rarely number of the loculi is reduced to 1, 2 or 4.

Common plants

(1) Litchi (*Nephelium litchi* Camb. = *Litchi chinensis* Sonner), a common fruit tree. (2) Longan (*Nephelium longana* Camb. = *Euphoria longana* Lamk.), often cultivated for its edible fruits. (3) Soapberry trees (*Sapindus trifoliatus* L. = *S. emarginatus* Vahl. and *S. mukorossi*

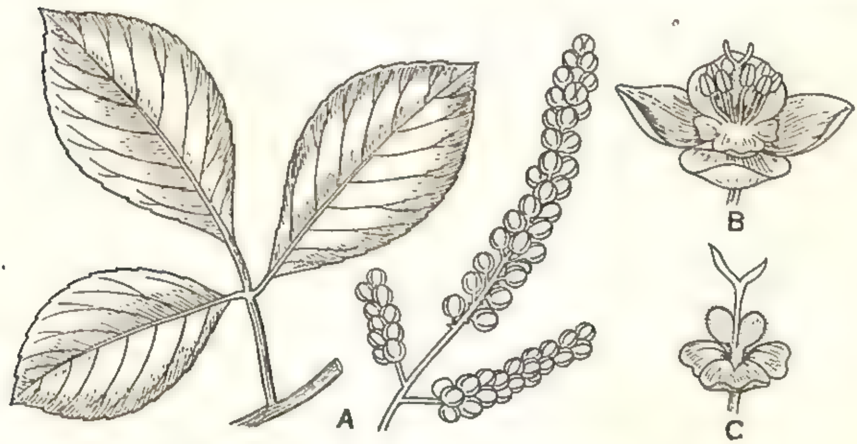


Fig. 589. Sapindaceae (*Allophyllus cobbe*).
A, A compound leaf and inflorescence; B, Staminate flower; C, Pistillate flower.

Gaertn.), yield fruits which make lather with water. (4) Baloon vine (*Cardiospermum halicacabum* L.), a common weed with wiry stem found in waste places. (5) *Allophyllus cobbe* Blume = *A. serratus* Radlk., a small tree or shrub sometimes met with in hedges. (6) *Aphania danura* Radlk., chiefly found in the Sundribans. (7) *Erioglossum edule* Blume, usually found in village-shrubberies. (8) Ceylon oak (*Schleichera trijuga* Willd. = *S. olesa* Oken.), a large tree. (9) *Dodonaea viscosa* Jacq., a shrub.

Affinity

This family is allied to Anacardiaceae from which it is distinguished by the pinnately compound leaves, mostly irregular polygamous flowers, scaly outgrowths on petals, usually eight stamens,

tricarpellate ovary and arillate seeds. Warburg is of opinion that Sabiaceae and Sapindaceae are two closely related families. The arillate seed establishes a link with Euphorbiaceae.

Economic importance

Economically, this family is not of much importance. *Nephelium litchi* yields a fleshy edible aril. Longan (*Nephelium longana*) also yields an inferior quality of edible aril. The pericarp of the fruits of soapberry trees (*Sapindus trifoliatus* and *S. mukorossi*) produces lather with water, which is used for cleansing woollen garments. The varnish tree (*Koelreuteria paniculata*) *Xanthoceras sorbifolia*, *Melicocca*, *Ungnadia* are ornamental plants.

Comparison between Sapindaceae and Anacardiaceae

Sapindaceae	*Anacardiaceae*
(1) Plants—trees or shrubs or tendril-climbers.	(1) trees or shrubs, with resinous juice.
(2) Leaves—usually compound.	(2) usually simple.
(3) Flowers—regular or irregular, bi- or uni-sexual, with disc between the petals and stamens.	(3) regular, bisexual but often becomes unisexual, with glandular disc between the stamens.
(4) Sepals—4-5, free.	(4) 3-5, united at the base.
(5) Petals—4-5, free.	(5) 3-5, free.
(6) Stamens—usually 8, free.	(6) 5+5 or less, free.
(7) Carpels—(3); ovary 3-celled, each cell containing one ascending ovule with a ventral raphe.	(7) 1; ovary usually 1-celled, containing one anatropous ovule with a dorsal raphe.
(8) Fruit—usually a nut or capsule.	(8) usually a drupe, sometimes nut.

BALSAMINACEAE

General characters

Plants—annual terrestrial herbs, sometimes aquatic (e.g., *Hydrocera*), with succulent stems. Leaves—alternate, opposite or whorled, simple, serrate, exstipulate. Flowers—irregular, bisexual, hypogynous. Sepals—5, *petaloid, the posterior one is very large and spurred*, imbricate. Petals—5, the anterior one is the largest. Stamens—5; filaments short and broad; *anthers united covering the pistil like a hood.* Carpels—(5); ovary superior, oblong, 5-celled with a row of pendulous anatropous ovules in each cell; *stigma sessile,*

often 5-*toothed*. Fruit—capsule, *dehisces explosively into 5 valves*. Seeds—exalbuminous with a straight embryo.

Number and distribution

This family consists of 2 genera, *Impatiens* and *Hydrocera*, and about 450 species which are commonly distributed on the hills.

Common plants

(1) Balsam (*Impatiens balsamina* L.), a herb commonly planted in gardens. (2) *I. roylei* is very common in the Himalayas. (3) *Hydrocera triflora* W. & A., an annual aquatic weed rooting at the nodes.

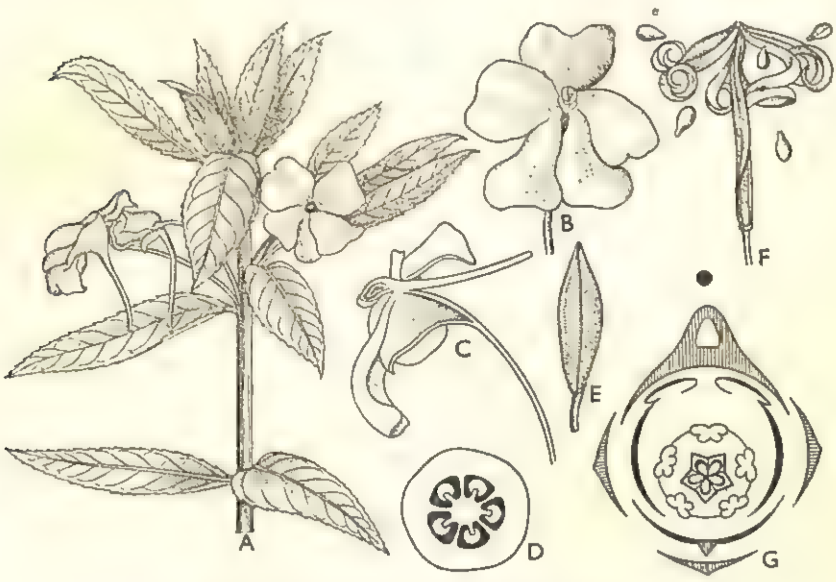


Fig. 590. Balsaminareae (*Impatiens balsamina*).
A, Portion of a flowering shoot; B, Flower; C, V.s. of the same; D, T.s. of ovary; E, Young fruit; F, Dehiscing mature fruit; G, Floral diagram.

Affinity

Balsaminaceae is distinguished from its allied families by the presence of a spurred sepal, union of anthers round the pistil, and elastic dehiscence of capsular fruit.

Economic importance

This family is of very little economic importance. Different species of *Impatiens* are planted in gardens as ornamentals.

ORDER 25. RHAMNALES

Usually woody plants, mostly climbing. Flowers bisexual, often with a tendency of unisexuality. Calyx-lobes very small or calyx entire. Intrastaminal disc well developed. Stamens in one whorl, as many as the sepals, antipetalous. Ovary usually with 1 or 2 ascending ovules.

According to Engler this Order consists of 2 families, viz., Rhamnaceae and Vitaceae. Bentham and Hooker have placed the aforesaid families in the cohort Celastrales under the subclass Polypetalae. In Hutchinson's system this Order (54th Order) consists of 4 families.

RHAMNACEAE

General characters

Plants—small trees or shrubs, sometimes climbing, often spiny. Leaves—alternate, simple, usually palmately veined, stipulate. Inflorescence—axillary corymb or cymose. Flowers—small, greenish, regular, bisexual (rarely unisexual), perigynous *with prominent disc*. Sepals—5, rarely 4, valvate. Petals—5, rarely 4, inserted on the edge of the fleshy disc lining the calyx-tube, usually *clawed and hooded*. Stamens—as many as petals, *antipetalous*, often hidden

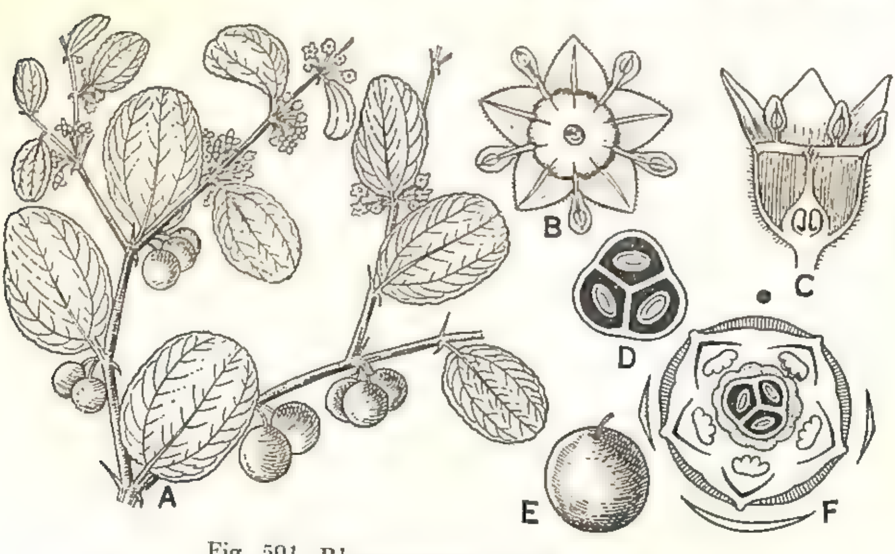


Fig. 591. Rhamnaceae (*Zizyphus jujuba*).
A, Portion of a flowering shoot; B, Flower; C, V.s. of the same; D, T.s. of ovary; E, Fruit; F, Floral diagram.

within the concave petals, inserted like the petals on the edge of the fleshy disc lining the calyx-tube. Carpels—(3); ovary superior but appears to be inferior, 3-celled with 1 *erect basal ovule* in each cell; stigma 5-lobed. Fruit—drupe, berry-like or capsule, rarely samaroid. Seeds—exalbuminous or albuminous with large and straight embryo.

Number and distribution

This family consists of 45 genera with 550 species, which are found in the tropical and subtropical regions.

KEY TO GENERA

A. Armed shrubs and trees with prominent 3-nerved leaves; ovary sunken in disc; fruit fleshy with hard 1-3-celled, 1-3-seeded core; seed albuminous .. .. *Zizyphus.*

B. Unarmed climbers

(*a*) Fruit samaroid, 1-celled, 1-seeded; seed exalbuminous *Ventilago.*

(*b*) Fruit 3-winged; fls. in panicled fascicles .. *Gouania.*

(*c*) Fruit terete; fls. subumbellate .. .. *Helinus.*

Common plants

(1) The Jujube tree (*Zizyphus jujuba* Lamk. = *Z. mauratiana* Lamk.), a small tree generally cultivated for its edible fruits. (2) *Z. oenoplia* Mill., a straggling shrub, commonly found in hedges. (3) *Ventilago maderaspatena* Gaertn., a strong climber. (4) *Gouania leptostachya* DC., another strong climber. (5) *Helinus lanceolatus* Brand., a scandent cirrhose shrub.

Affinity

This family is closely related to Vitaceae, as it is evident from almost similar floral structures. It also bears affinity with Celastraceae, the main distinction is the antipetalous stamens. It differs from Vitaceae in having simple leaves and in the structure of the receptacle. Rhamnaceae is readily distinguished by the simple unlobed leaves, perigynous flowers, antipetalous stamens and basal ovules.

Economic importance

This family contains some ornamental plants, such as, *Rhamnus*, *Ceanothus*, *Zizyphus*, *Hovenia spyridum*, etc. *Zizyphus jujuba* yields edible and tasty fruits. A purgative, *cascara sagrada*, is obtained from the Californian species, known as *Rhamnus purshiana*.

VITACEAE

General characters

Plants—mostly climbing shrubs with tendrils, or small trees, with swollen nodes. Leaves—alternate, simple but often digitately or pinnately 3-9-foliate, stipulate or exstipulate. Inflorescence—leaf-opposed spikes, racemes, panicles or cymes. Flowers—small greenish, regular, bisexual (sometimes unisexual), hypogynous or slightly perigynous, *with prominent annular or lobed disc*. Sepals—4-5, free or united at the base, apparently absent. Petals—4-5,

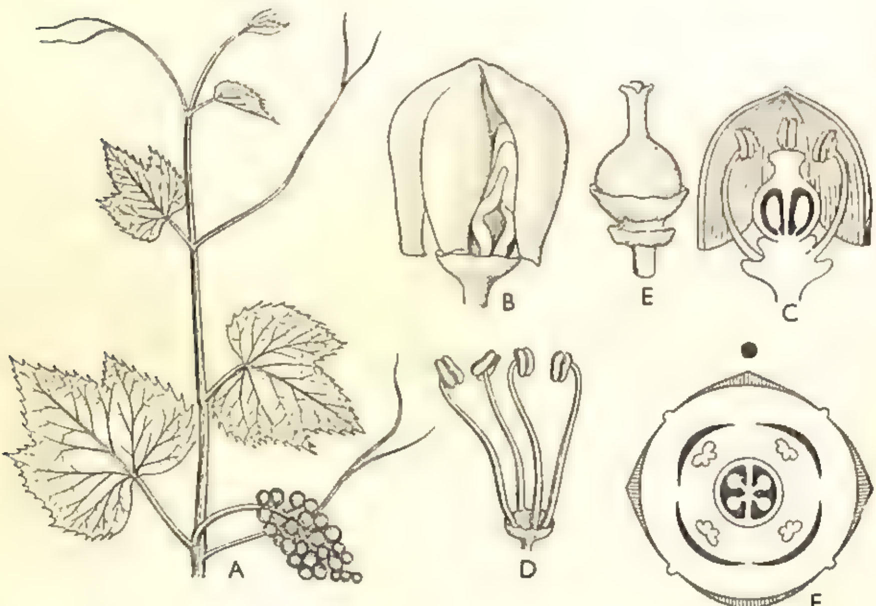


Fig. 592. Vitaceae (*Vitis vinifera*).
A, Portion of a plant; B, Flower; C, V.s. of the same; D, Stamens; E, Pistil; F, Floral diagram.

valvate, *caducous*. Stamens—4-5, antipetalous, free arising from the base of the disc but in *Leea* joined at the base to form a tube, which is united to the corolla. Carpels—usually (2), sometimes (3-8) as in *Leea;* ovary superior, 2-celled (e.g., *Vitis*) or 3-6-celled (e.g., *Leea*), usually with 1-2 ovules in each cell; stigma *capitate or discoid*. Frui. —*berry*. Seeds—with a strong or bony coating, and with *copious oily endosperm and a small straight embryo*.

Number and distribution

This family consists of 11 genera and about 600 species which are chiefly found in the tropical and subtropical regions.

KEY TO GENERA

A. Tendril-climbers; fls. in raceme or cyme clusters; stamens free; ovary 2-celled, ovules 2 in each cell .. .. *Vitis.*

B. Erect shrubs; large leaves with sheathing petioles; stamens connate; ovary 3-6-celled, 1 ovule in each cell .. *Leea.*

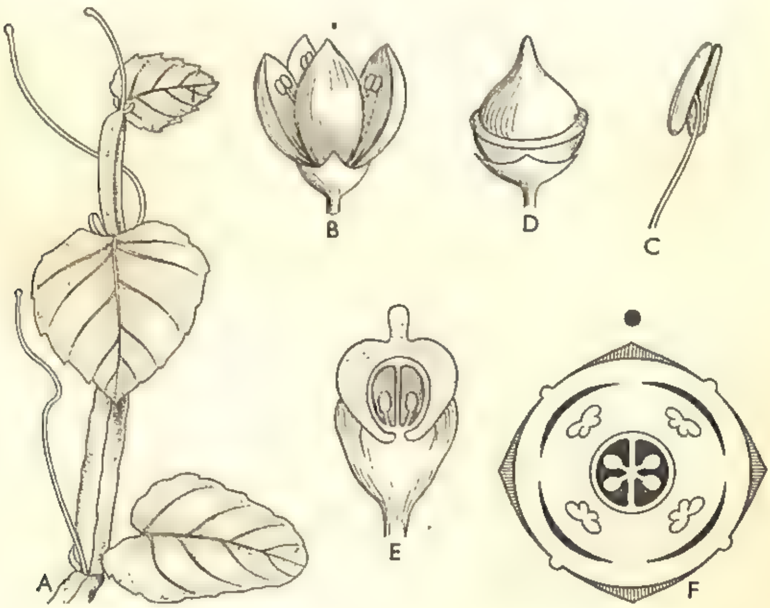


Fig. 593. Vitaceae (*Vitis quadrangularis*).
A, Portion of a shoot: B, Flower; C, Stamen; D, Pistil; E, L.s. of ovary; F, Floral diagram.

Common plants

(1) *Vitis quadrangularis* Wall. = *Cissus quadrangularis* L., a common climber with square stems. (2) *Vitis pedata* Vahl. = *Cayrotia pedata* Gegnep., and *Vitis setosa* Wall. = *Cissus setosa* Roxb., commonly found in villages and have medicinal value. (3) *Vitis trifolia* L., very common. (4) Grape vine (*Vitis vinifera* L.). (5) *Leea macrophylla* Roxb. = *Cayrotia carnosa* Gegnep., an erect herb without tendrils, chiefly found along Siliguri Road to Sukna. (6) *Leea acquata* L., a shrub 4-10 ft. high. (7) *L. herbacea* Ham., another shrub 12-16 ft. high.

Affinity

This family bears an affinity with Rhamnaceae and members of Celastrales in the plan of floral structures, but is readily distinguished by the climbing habit, berried fruit, leaf-opposed inflorescence, antipetalous stamens, capitate or discoid stigma, and seeds with copious endosperm and small embryo. This family is considered to have been derived from Rutaceae by the suppression of antisepalous whorl of stamens.

Economic importance

This family is economically important. *Vitis vinifera* yields edible fruits from which raisins and a sort of wine are obtained. Some plants are ornamentals, such as Boston ivy (*Parthenocissus tricuspidata*), Virginia creeper (*P. quinquefolia*), etc.

ORDER 26. MALVALES

Plants herbs, shrubs or trees, often with mucilage and stipulate leaves. Flowers usually bisexual, actinomorphic, cyclic, hypogynous. Perianth mostly pentamerous. Calyx valvate. Stamens usually numerous, monadelphous, polyadelphous or free with tendency of union at the base. Ovary multicarpellary. Placentation axile.

According to Engler this Order consists of 4 suborders containing 8 families, viz., Tiliaceae, Malvaceae, Bombacaceae, Sterculiaceae, etc. Bentham and Hooker designated this Order as cohort Malvales consisting of 3 families, viz., Malvaceae, Sterculiaceae and Tiliaceae; Bombacaceae had no separate existence and was included in Malvaceae: In Hutchinson's system this Order (36th Order) consists of 1 family Malvaceae only, while the other families have been put under the Order Tiliales (35th Order) which contains 5 families.

TILIACEAE

General characters

Plants—generally trees or shrubs, sometimes herbs (e.g., *Corchorus*) with mucilage. Leaves—alternate, simple, entire or toothed, often oblique, stipulate. Inflorescence—typically *cymose*. Flowers—regular, bisexual (rarely unisexual), hypogynous. Sepals—5,

free or united at the base, caducous, valvate. Petals—5, or fewer or 0, free, imbricate or valvate. Stamens—10-numerous, free or slightly united at the base or in 5-10 bundles (*polyadelphous*), *usually inserted at the base of the petals* but sometimes raised above the corolla by the development of an internode (*androgynophore*), as in *Grewia*, intrastaminal disc present; anthers 2-celled. Carpels—(2-5); ovary superior, 2-10-celled with 1-many ascending or pendulous

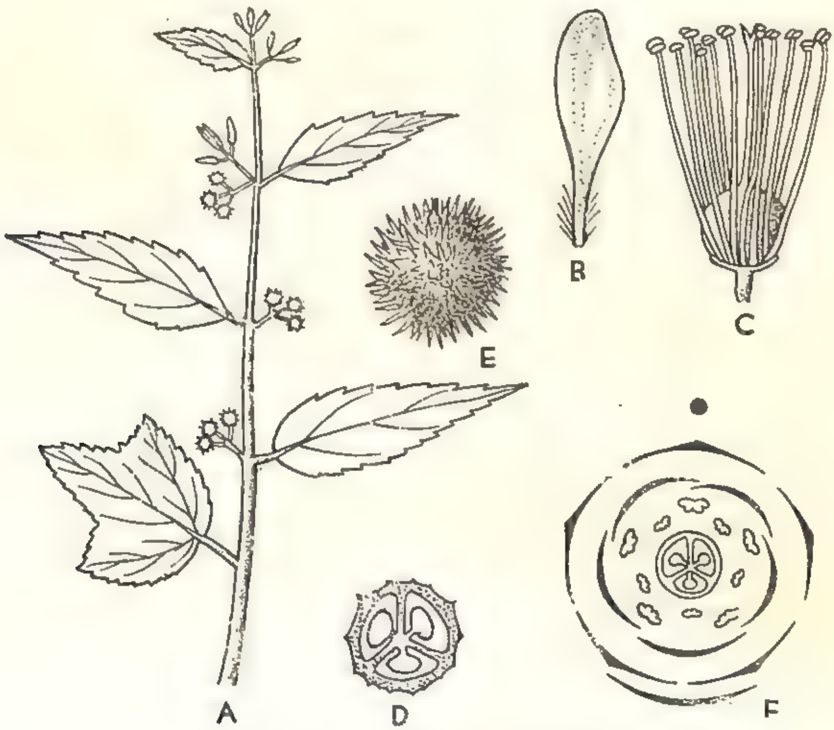


Fig. 594. Tiliaceae (*Triumfetta rhomboidea*).
A, Portion of a flowering shoot; B, Petal; C, Flower with sepals and petals removed; D, T.s. of ovary; E. Fruit; F, Floral diagram.

ovules; style 1; stigmas as many as the locules. Fruit—fleshy (drupaceous) or dry (capsule), indehiscent or dehiscent. Seed—albuminous with a curved embryo and leafy cotyledons.

Number and distribution

This family consists of 41 genera and about 400 species which are chiefly found in the tropics.

KEY TO GENERA

A. Sepals united into cup

Anther-cells confluent; staminodes present in the inner whorl .. .. *Brownlowia.*

Stamens on a shortened axis, staminodes absent .. *Berrya.*

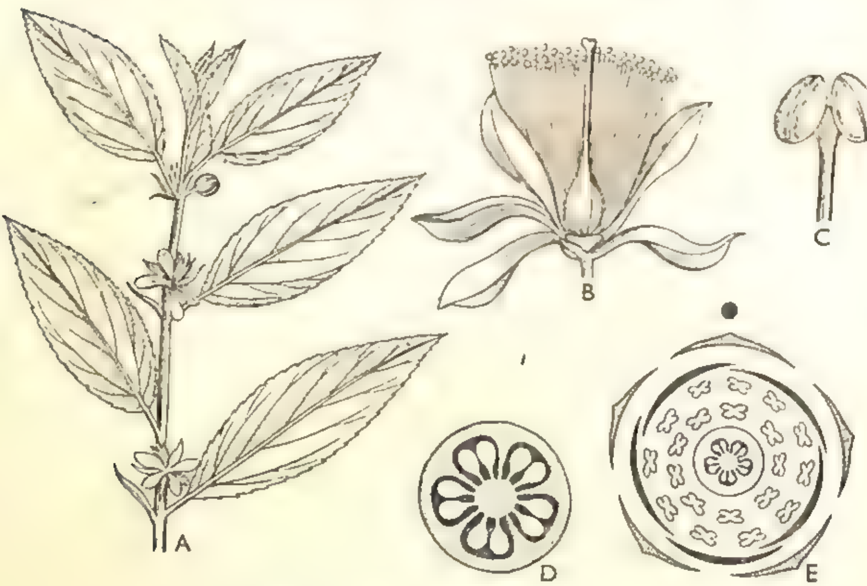


Fig. 595. Tiliaceae (*Corchorus capsularis*).
A, Portion of a flowering shoot; B, Flower; C, Stamen;
D, T.s. of ovary; E, Floral diagram.

B. Sepals free

(*a*) Petals not clawed or glandular

(*i*) Fruit a many-seeded capsule; plant usually herb .. .. *Corchorus.*

(*ii*) Fruit a fleshy drupe; plant tree or shrub .. *Elaeocarpus.*

(*b*) Petals with a thickened or glandular claw

(*iii*) Fruit smooth drupaceous; leaves 3-9-nerved .. *Grewia.*

(*iv*) Fruit prickly, globose, indehiscent or separating into 3-5 cocci .. .. .. *Triumfetta.*

Common plants

(1) Jute (*Corchorus capsularis* L. and *C. olitorius* L.). (2) *Corchorus acutangulus* Lamk. = *C. aestuons* L., a common weed of waste places, the leaves of which have medicinal value. (3) *Grewia asiatica* L. =

G. subinaequalis DC., a commonly planted fruit tree. (4) Spiny cocklebur (*Triumfetta rhomboidea* Jacq. = *T. bartramia* L.), a common weed with hooked spines on fruit. (5) Bead-tree (*Elaeocarpus ganitrus* Roxb. = *E. sphaericus* K. Schum.), the seeds of which are ornamented and strung together into beads. (6) *E. floribundus* Bl., commonly found in North Bengal. (7) *Brownlowia lanceolata* Benth., commonly found in Sundribans. (8) *Muntingia callabura* L., a common garden plant. (9) *Berrya ammonilla* Roxb., a timber tree.

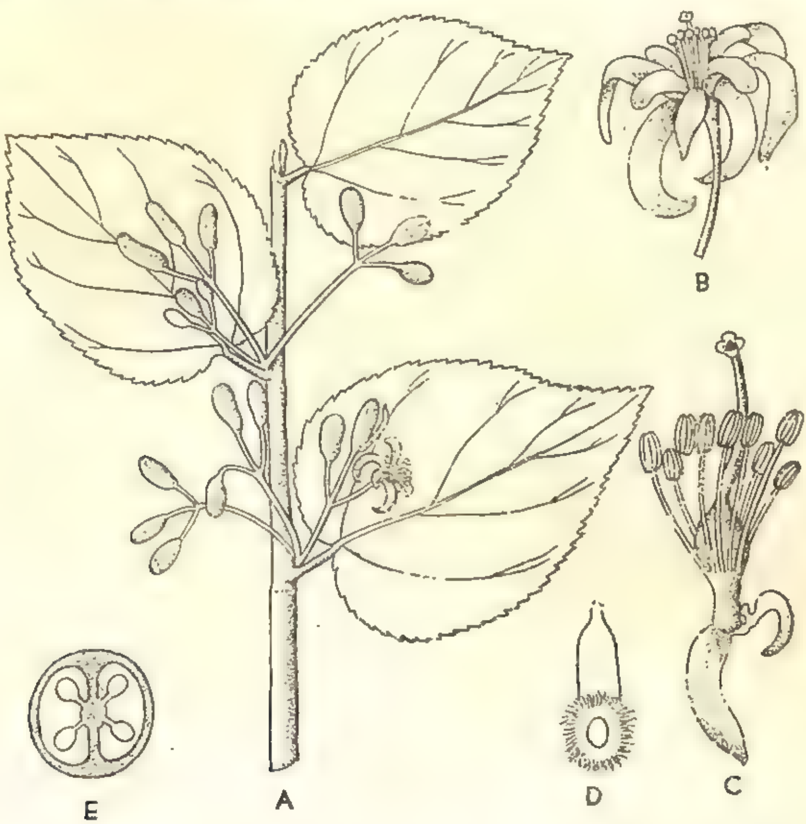


Fig. 596. Tiliaceae (*Grewia asiatica*).
A, Portion of a flowering shoot; B, Flower; C, The same after removal of all but one sepal and one petal; D, Gland at the base of the petal; E, T.s. of ovary.

Affinity

This family is allied to Malvaceae and Steruliaceae but readily distinguished by the free or polyadelphous stamens, 2-celled anthers, presence of a disc, and typically cymose inflorescence.

Economic importance

Tiliaceae is economically important. The plants of this family generally possess mucilagenous juice and fibrous bark. The most

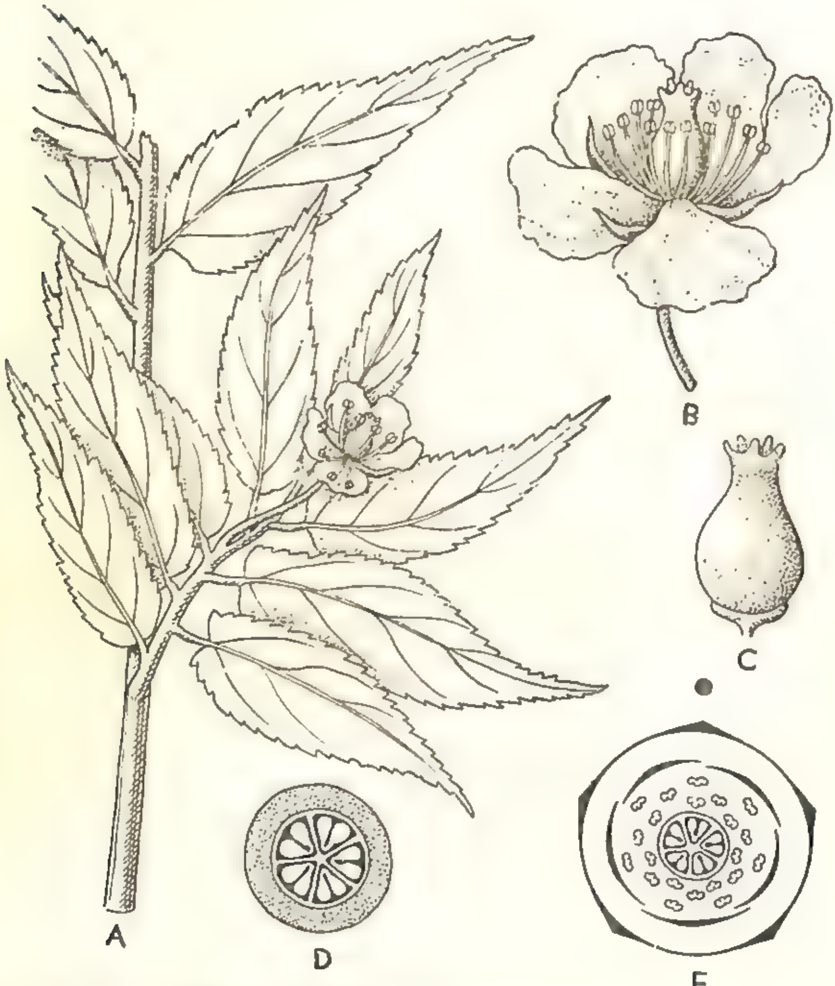


Fig. 597. Tiliaceae (*Muntingia callabura*).
A, Portion of a flowering shoot; B, Flower; C, Pistil; D, T.s. of ovary; E, Floral diagram.

important plants are *Corchorus capsularis* and *C. olitorius* which yield fibres. *Grewia* yields edible fruits. The seeds of *Elaeocarpus* are strung into beads. Species of *Grewia*, *Corchoropsis*, *Entelea*, etc., are ornamentals.

MALVACEAE

General characters

Plants—usually herbs or shrubs, *often mucilagenous* and with stellate hairs on young parts. Leaves—alternate, simple, entire or variously lobed, mostly palmately veined, stipulate (*free-lateral stipules*). Inflorescence—cymose. Flowers—regular, bisexual (unisexual in *Napaea*), hypogynous, often showy, cyclic. Sepals—5, more or less united, *often subtended by an epicalyx* (excepting *Sida*,

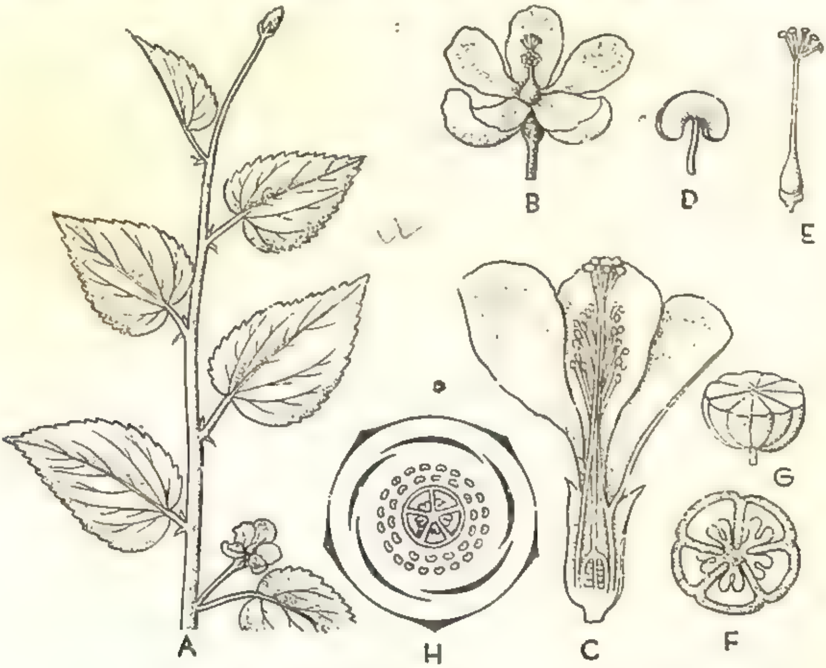


Fig. 598. Malvaceae (*Sida cordifolia*).
A, Portion of a flowering shoot; B, Flower; C, V.s. of the same; D, Stamen; E, T.s. of ovary; G, Fruit; H, Floral diagram.

Abutilon, etc.), valvate. Petals—5, free from one another but adnate at the base to the staminal tube, *twisted*. Stamens—numerous, usually *monadelphous*, with *reniform, 1-celled anthers; pollen grains large and spiny*. Carpels—(1 to numerous); ovary 1-many-celled, but often 5-celled, with 1-*many anatropous ovules in each cell* and placed at the bottom of the staminal tube; style 1; stigmas as many or twice as many as carpels. Fruit—capsule or schizocarp, sometimes berry (e.g., *Malvaviscus*). Seeds —reniform, naked or comose with *curved embryo* and folded *cotyledons*.

Number and distribution

This family consists of about 82 genera and 1500 species which are cosmopolitan excepting in very cold regions.

KEY TO GENERA

A. Fruit capsular
- (1) Stigma spreading and seeds reniform
  - (*i*) Ovary 5-celled .. .. .. *Hibiscus.*
  - (*ii*) Ovary 3-celled .. .. .. *Kydia.*
- (2) Stigma cohering in a club-shaped mass
  - (*iii*) Bracteoles (epicalyx) 3, large, cordate; seed cottony .. .. *Thespesia.*

B. Fruit of ripe carpels separating from the axis
- (3) Styles as many as carpels
- (*a*) Epicalyx absent, without false septum
  - (*iv*) Ovules 2 or more, ascending, reniform .. *Abutilon.*
  - (*v*) Ovule solitary; fls. small .. .. *Sida.*
- (*b*) Epicalyx of 3 distinct bracteoles
  - (*vi*) Stigmas linear; carpels numerous .. .. *Malva.*
  - (*vii*) Stigmas capitate; carpels 8-12 .. .. *Malvastrum.*
- (*c*) Epicalyx of 6-9 bracteoles, united at base .. *Althaea.*
- (4) Styles twice as many as carpels
  - (*viii*) Bracteoles 10; carpels opposite to sepals .. *Pavonia.*
  - (*ix*) Bracteoles 5; carpels opposite to petals .. *Urena.*
  - (*x*) Bracteoles 0 or mixed with fls. in dense heads; carpels unarmed .. .. .. *Malachra.*
  - (*xi*) Epicalyx present; carpels 10 .. .. *Malvaviscus.*

Range of floral structures

This family does not show wide variation in floral structure. Epicalyx is present in *Malva*, *Hibiscus*, *Althea* and *Lavetere*, but absent in *Sida* and *Abutilon.* There are 3 epicalyces in *Gossypium.*

Variation in the number of carpels also occurs. Its number ranges from one to many. The number of carpels in *Abutilon* is 15-20; in *Malva* numerous; in *Malvastrum* 8-10 carpels; in *Plagianthus* 2 or 1; in *Malope trifida* numerous carpels are vertically arranged.

Styles as many as carpels, e.g., *Abutilon*, *Sida*, *Malva*, and *Althea;* but twice as many as carpels in *Pavonia*, *Kydia*, *Urena*, and *Malachra.*

Stigma is spreading in *Hibiscus* and *Kydia*, but connate into a club-shaped mass in *Thespesia;* ovary 3-celled in *Kydia*, but 5-celled in *Hibiscus*.

The position and number of ovules in the ovarian chamber also varies. Generally, the ovules are ascending but may be pendulous or horizontal; 2-ovuled ovary-chamber is found in *Abutilon*, but 1-ovuled ovary-chamber occurs in *Sida* and *Malachra*.

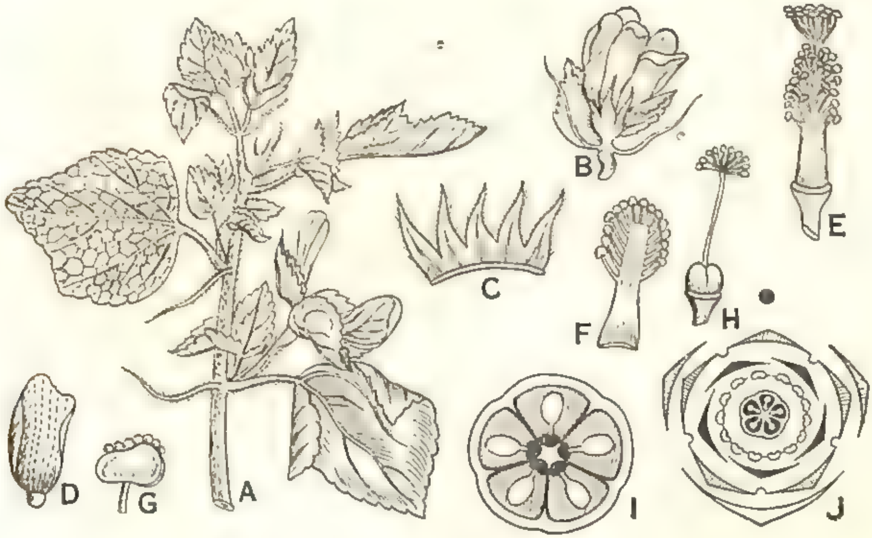


Fig. 599. Malvaceae (*Malachra capitata*).
A, Portion of a flowering shoot; B, Flower; C, Calyx; D, Petal; E, The same after removal of calyx and corolla; F, Stamens; G, Anther; H, Pistil; I, T.s. of ovary; J. Floral diagram.

Common plants

(1) Cotton plant (*Gossypium herbaceum* L.), a shrub commonly cultivated for cotton. (2) China rose (*Hibiscus rosa-sinensis* L.), a common ornamental shrub. (3) Lady's finger (*Hibiscus esculentus* L. = *Abelmoschus esculentus* Moench.), cultivated throughout India for its fruit which is a vegetable; Roselle (*H. sabdariffa* L.), commonly cultivated for its fleshy calyx which is used in making pickles and jelly. (4) Changeable rose (*Hibiscus mutabilis* L.), often planted in gardens for the sake of flower, the petals of which change from white to red in the course of a day. (5) Deccan hemp (*Hibiscus cannabinus* L.), commonly cultivated for fibres. (6) *Urena lobata* L. and *U. sinuata* L.

are common weeds found everywhere. (7) Indian Mallow (*Abutilon indicum* Don.), commonly found in bushes; *A. hirtum* G. Don., an erect woody herb. (8) Different species of *Sida*, e.g., *S. cordifolia* L., *S. acuta* Burm., *S. rhombifolia* L., *S. rhomboidea* Roxb., and *S. humilis* Willd. =*S. veronicaefolia* L. are common weeds on waste places and roadsides. (9) Portia tree or Tulip tree (*Thespesia populnea* Corr. = *Hibiscus populneus* L.), often planted as an avenue tree. (10) *Malachra capitata* L., a common weed of waste places. (11) Tree mallow (*Hibiscus tiliaceous* L.), a small tree found in Sundribans and also along river

Fig. 600. Malvaceae (*Gossypium herbaceum*).
A, Portion of a flowering shoot; B, V.s. of a flower; C, Monadelphous stamen; D, Stamen; E, T.s. of ovary; F, Young fruit; G, Ripe dehiscent fruit; H, Floral diagram.

banks as far north as Calcutta. (12) *Malvastrum tricuspidatum* Gray =*M. coromandelianum* Garcke, found in hedges and waste places. (13) *Pavonia odorata* Willd., a weed of fields and waste places. (14) *Kydia calycina* Roxb., a tree.

Affinity

This family is closely allied to Tiliaceae, Bombacaceae and Sterculiaceae in its general characters and aestivation of calyx but readily distinguished by monadelphous stamens, 1-celled anthers, large, spiny pollen grains, twisted corolla and presence of epicalyx.

Economic importance

Malvaceae is of greatest economic importance. *Gossypium* is the most important plant which produces cotton of commerce; oil is extracted from the seeds for burning lamps and the oil-cake may be used as a fodder. *Hibiscus cannabinus* yields good fibres. Fruits of lady's finger are used as vegetable. *Hibiscus*, *Althea*, *Malva*, *Malvaviscus*, *Callirhoe*, etc., are ornamentals.

BOMBACACEAE

General characters

Plants—tall trees, often with very thick base and spreading

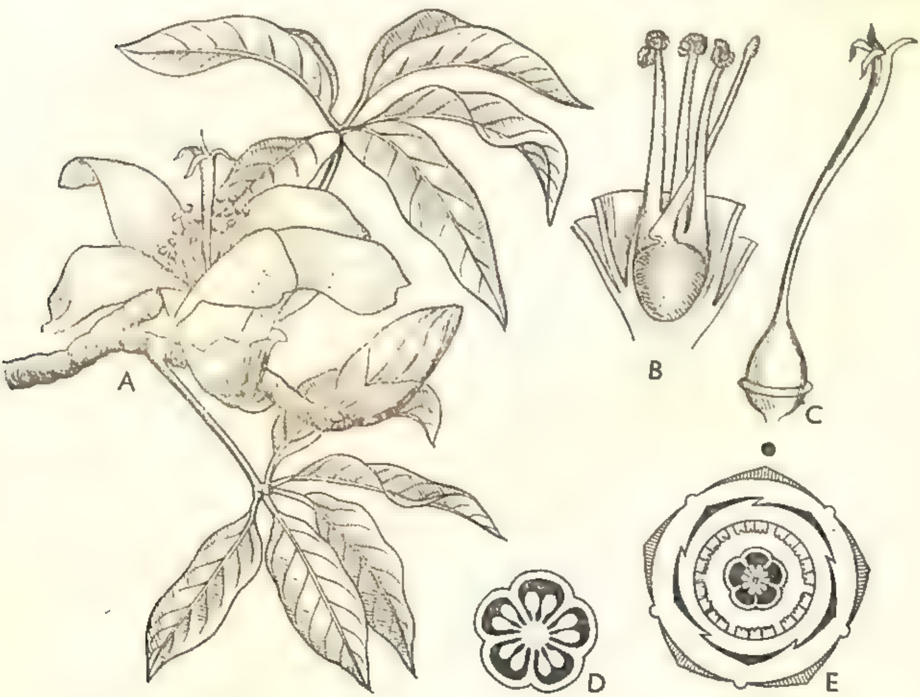


Fig. 601. Bombacaceae (*Bombax malabaricum*).
A, Portion of a flowering shoot; B, V.s. of a flower after removal of calyx and corolla; C, Pistil; D, T.s. of ovary; E, Floral diagram.

branches. Leaves—alternate, usually palmately compound (digitate), stipulate. Flowers—large and showy, regular, bisexual, hypogynous, bracteate, sometimes subtended by an epicalyx (e.g.,

Adansonia). Sepals—5, free or slightly united at the base, valvate. Petals—5, sometimes 0, twisted. Stamens—5-numerous, free or *polyadelphous* (e.g., *Bombax*); *staminodes often present; anthers 1-celled; pollen grains smooth.* Carpels—(2-5); ovary superior, 2-5-celled with 2 or more erect anatropous ovules in each cell; style 1, capitate or lobed; stigmas 1-5. Fruit—capsule or berry-like. Seeds—smooth, occasionally arillate, with or without endosperm, *sometimes embedded in the pith-like tissue or in a wooly outgrowth of the pericarp.*

Number and distribution

This family consists of 22 genera and 140 species which are exclusively distributed in the tropics.

Common plants

(1) Red silk-cotton tree (*Bombax malabaricum* DC. = *Salmalia malabarica* Schott.), a huge tree with buttersssed trunk which yields stuffing-cotton. (2) White silk-cotton tree (*Eriodendron anfractuosum* DC. = *Ceiba pentandra* Kurz.), a tall tree which yields 'kapok' of commerce. (3) The Baobab tree (*Adansonia digitata* L.), a thick-based spreading tree.

KEY TO GENERA

(*a*) Fruit dehiscent; seeds packed; calyx truncate or toothed
  (*i*) Fls. red, stamens many .. .. .. *Bombax.*
  (*ii*) Fls. white, stamens few .. .. .. *Eriodendron.*
(*b*) Fruit indehiscent; seeds embedded in a mealy pulp; epicalyx present .. .. *Adansonia.*

Affinity

This family is allied to other families under the Order Malvales but is readily distinguished by the smooth pollen grains, presence of many staminodes and the pericarp of the fruit (pithy to woolly).

Economic importance

This family is economically important. Red silk-cotton tree (*Bombax*) yields cotton for stuffing pillows. White silk-cotton tree (*Eriodendron*) yields the 'kapok' of commerce. The Baobab tree (*Adansonia*), *Bombax*, the Brazilian floss-silk tree (*Chorisia*), the guinea chestnut (*Pachira*), etc., are ornamentals.

STERCULIACEAE

General characters

Plants—generally trees or shrubs, sometimes herbs with mucilage. Leaves—alternate, simple, entire or palmately lobed, or compound, stipulate. Inflorescence—usually cymose, axillary or terminal. Flowers—regular or less often zygomorphic, bisexual (sometimes unisexual, e.g., *Heritiera*, *Sterculia*), hypogynous. Sepals—3-5, more or less slightly united at the base, valvate. Petals—5, often reduced in size, (sometimes absent, e.g., *Heritiera*, *Sterculia*), free, sometimes adnate to the base of the androecium, twisted.

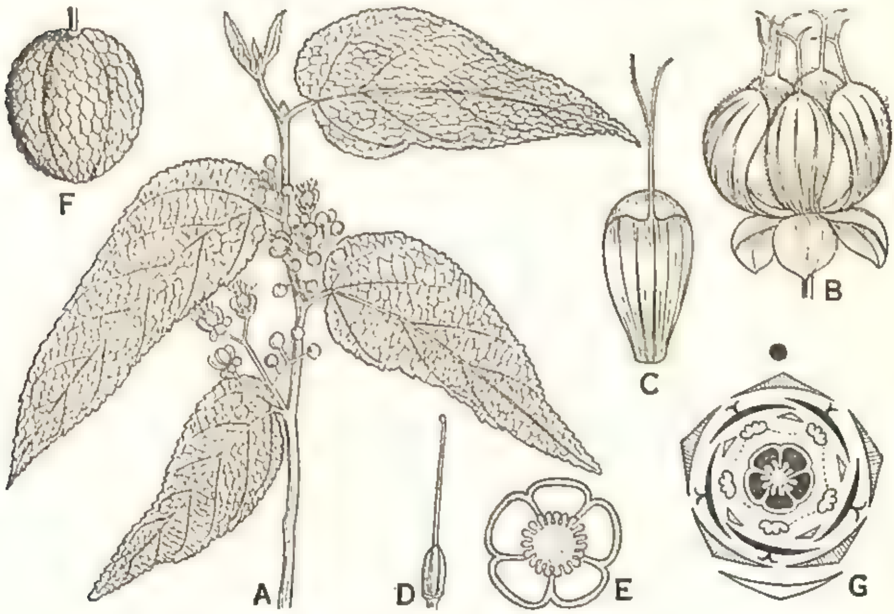


Fig. 602. Sterculiaceae (*Guazuma tomentosa*).
A, Portion of a flowering shoot; B, Flower; C, Petal; D, Pistil;
E, T.s. of ovary; F, Fruit; G, Floral diagram.

Stamens—numerous in two whorls (those of outer whorl staminodial or 0, and those of inner whorl usually fertile) or monadelphous; *anthers 2-celled.* Carpels—(4-5), sometimes almost free excepting the styles and stigmas (e.g., *Sterculia*); ovary superior, *often stalked*, 4-5-celled with two to numerous anatropous ovules in each cell; styles as many as carpels, free or united. Fruit—capsule or follicle, dehiscing along the ventral suture. Seeds—with fleshy endosperm and an embryo with *flat, folded or rolled, leafy cotyledons.*

Number and distribution

This family consists of 50 genera and about 750 species which are found in tropical and subtropical regions.

KEY TO GENERA

A. Flowers unisexual or polygamous; petals 0
  (*a*) Staminal column with ring of sessile anthers
    (*i*) Anthers 5-25; ripe carpels dehiscent .. *Sterculia.*
    (*ii*) Anthers 5; ripe carpels indehiscent .. *Heritiera.*

B. Flowers bisexual
  (*b*) Petals flat, deciduous; anthers alternating with staminodes
    (*iii*) Leaves oblique below; ovary within the staminal column; anther-cells parallel; seeds winged .. *Pterospermum.*
    (*iv*) Leaves simple; ovary at the top of the staminal column; anther-cells divaricate: capsule woody with wingless seed .. .. .. *Helicteres.*
  (*c*) Petals flat, persistent; anthers alternating with staminodes
    (*v*) 15 anthers in 5 groups of 3, alternating with staminodes .. .. .. *Pentapetes.*
    (*vi*) Ovary 5-celled; styles 5 .. .. *Melochia.*
    (*vii*) Ovary 1-celled, monocarpellary .. .. *Waltheria.*

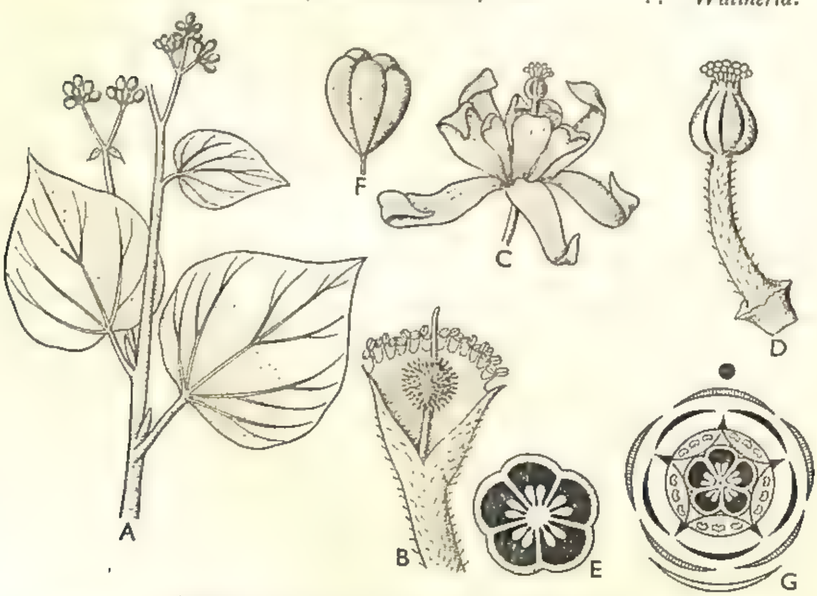


Fig. 603. Sterculiaceae (*Kleinhovia hospita*).
A, Portion of a flowering shoot; B, Flower bud; C, Flower; D, Staminal column; E, The same split open; F, T.s. of ovary; G, Floral diagram.

(*d*) Petals deciduous, unequal; capsule, inflated pyriform *Kleinhovia.*

(*e*) Petals concave; anthers in groups between each pair of staminodes

(*viii*) Petals clawed; fruit membraneous; 5-angled 5-winged capsule, truncated above; ovules many in each loculus .. .. *Abroma.*

(*ix*) Fruit woody, tubercled capsule, globose; ovules many in each loculus .. .. .. *Guazuma.*

(*x*) Petals ligulate; fruit armed, prickly or bristly capsule; ovules 2 in each loculus .. *Buettneria*

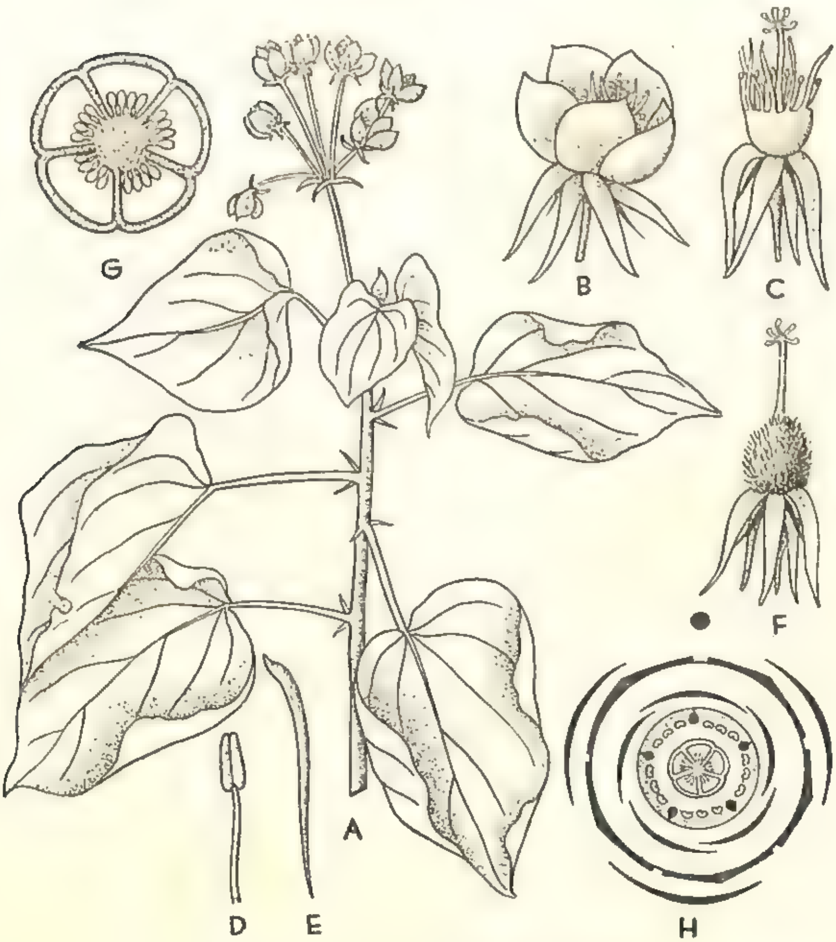


Fig. 604. Sterculiaceae (*Dombeya mastersii*).
A, Portion of a flowering shoot; B, Flower; C, The same with petals removed; D, Stamen; E, Staminode; F, Pistil; G, T.s. of ovary; H, Floral diagram.

Common plants

(1) *Sterculia foetida* L. and *S. colorota* = *Firmiana colorata* R. Br. are large trees planted on roadsides. (2) *S. alata* Roxb., an avenue tree. (3) *Abroma augusta* L., chiefly planted for medicinal purposes. (4) *Pterospermum acerifolium* Willd., an avenue tree which produces fragrant flowers with fleshy sepals; *P. semisagittatum* Ham., another common tree. (5) *Heritiera minor* Roxb., abundantly found in the Sundribans which yields the best fire-wood. (6) *Helicteres isora* L.,

Fig. 605. Sterculiaceae (*Helicteres isora*).
A, Portion of a flowering shoot; B, Petals; C, Calyx split open; D, Flower with sepals and petals removed; E, T.s. of ovary; F, Floral diagram.

a shrub with spirally twisted follicles. (7) *Kleinhovia hospita* L., commonly planted on roadsides. (8) *Melochia corchorifolia* L., a common weed of waste places, dry-fields and grassy glades. (9) Bastard cedar (*Guazuma tomentosa* Kunth.). (10) Noon-flower (*Pentapetes phoenicea* L.), a common garden herb with pink-red flowers. (11) Cocoa tree (*Theobroma cacao*), chiefly cultivated in Southern India and Ceylon for preparing cocoa and chocolate from the seeds. (12) *Waltheria indica* L., a common weed of waste places.

(13) *Buettneria herbacea* Roxb., a herb. (14) *Dombeya mastersii*, a common ornamental garden plant.

Affinity

This family is allied to Tiliaceae, Malvaceae and Bombacaceae, but readily distinguished by the absence of epicalyx, definite number of stamens and stalked ovary. It differs from Malvaceae in having 2-celled anthers, and from Bombacaceae in presence of copious endosperm, androecium of typically 5 fertile stamens alternated with equal number of staminodes, and absence of a pithy or woolly pericarp.

Fig. 606. Sterculiaceae (*Pterospermum acerifolium*).
A, Portion of a flowering shoot;. B, Fruit; C, Flower; D, Floral diagram.

Economic importance

This family is economically important. The most important plant is *Theobroma* from the seeds of which cocoa and chocolate are prepared. The root of *Abroma* is used in medicine. *Heritiera* supplies fire-wood. Some plants are ornamentals, such as *Sterculia*, *Dombeya*, *Cola*, etc.

Comparison of Tiliaceae, Malvaceae, Bombacaceae and Sterculiaceae

Tiliaceae	*Malvaceae*	*Bombacaceae*	*Sterculiaceae*
1. Plants—usually trees or shrubs, sometimes herbs.	1. Usually herbs or shrubs, often with mucilage.	1. Tall trees often with thick base.	1. Usually trees or shrubs, sometimes herbs.
2. Leaves—alternate, simple, often oblique, stipulate.	2. Alternate, simple, stipulate.	2. Alternate, usually digitate.	2. Alternate, simple, stipulate.
3. Flowers—regular, bi- or uni-sexual, hypogynous.	3. Regular, bisexual, hypogynous.	3. Regular, bisexual, hypogynous.	3. Regular or irregular, bi- or uni-sexual.
4. Sepals—5, free or united.	4. 5, usually surrounded by epicalyx.	4. 5, free or slightly united at the base, sometimes surrounded by an epicalyx.	4. 3-5, free or slightly united at the base.
5. Petals—5 or less or 0, free, imbricate.	5. 5, almost free, twisted.	5. 5, sometimes 0, twisted.	5. 5, often reduced in size or 0, twisted.
6. Stamens—10-numerous, free or slightly united, or polyadelphous, usually inserted at the base of the petals, rarely situated on an androgynophore.	6. Numerous, usually monadelphous.	6. 5-numerous, free or polydelphous, staminodes often present.	6. Numerous in two whorls, those of the outer whorl staminodial or 0 but of the inner whorl fertile, or monadelphous.
7. Anthers—2-celled.	7. Reniform, 1-celled; pollen grains spiny.	7. 1-celled; pollen grains smooth.	7. 2-celled.
8. Carpels—(1-5).	8. (2-many).	8. (2-5).	8. (4-5).
9. Ovary—2-10-celled with 1-many ascending or pendulous ovules in each cell.	9. 2-many-celled with 1 or more ovules in each cell.	9. 2-5-celled with 2 or more erect anatropous ovules in each cell.	9. Often stalked, 5-celled with 2-numerous anatropous ovules in each cell.
10. Fruit—fleshy or dry (capsule), dehiscent or indehiscent.	10. Capsule or schizocarp.	10. Capsule or berry-like.	10. Capsule or follicle.

ORDER 27. PARIETALES

Flowers regular or zygomorphic, usually bisexual. Perianth pentamerous, differentiated into calyx and corolla. Calyx imbricate. Stamens isomerous with the perianth members or more. Carpels (3); ovary unilocular with parietal placentation; ovules many. Disc is often present. Seeds albuminous.

According to Engler, this Order consists of 11 suborders containing 29 families, viz., Guttiferae, Dipterocarpaceae, Violaceae, Passifloraceae, etc. Rendle has divided this Order into 10 families. Bentham and Hooker have put Guttiferae and Dipterocarpaceae in the cohort Guttiferales, Passifloraceae in the cohort Passiflorales and Violaceae in the cohort Parietales under the subclass Polypetalae. In Hutchinson's system the name of the Order has been discarded. Guttiferae has been put under the Order Guttiferales (34th Order), Dipterocarpaceae under the Order Theales (32nd Order), Violaceae under the Order Violales (12th Order) and Passifloraceae under the Order Passiflorales (29th Order).

GUTTIFERAE

General characters

Plants—trees or shrubs with yellowish or greenish juice. Leaves—usually opposite or whorled, simple, coriaceous, exstipulate. Inflorescence—cymose. Flowers—regular, usually unisexual (sometimes bisexual), hypogynous. Sepals—2-10, or more, imbricate. Petals—4-12, imbricate. Stamens—few or numerous, free or more or less united into several bundles (*polyadelphous*). Carpels—usually (3 or 5), sometimes more or fewer (2-1); ovary superior, generally 1-many-celled, with 1 to numerous anatropous ovules in each cell; styles equal to the number of carpels or chambers, and united. Fruit—drupe or capsule. Seed—exalbuminous with large straight embryo.

Number and distribution

This family consists of about 35 genera and 400 species which are chiefly tropical.

KEY TO GENERA

A. Ovary with 2 erect ovules in each cell;

Ovary 2-celled; style long; embryo with a small radicle and 2 large cotyledons; petals 4 .. .. *Mesua.*

B. Ovary with ovules solitary in each cell—

(a) Ovary 1-celled with solitary erect ovule; style long: embryo with a small radicle and 2 large cotyledons; petals 4 or 0 .. .. *Calophyllum.*

(b) Ovary 2-12 celled with a solitary ovule attached to the inner angle of each cell; embryo with a large radicle and 2 small cotyledons; petals 4-5 .. *Garcinia.*

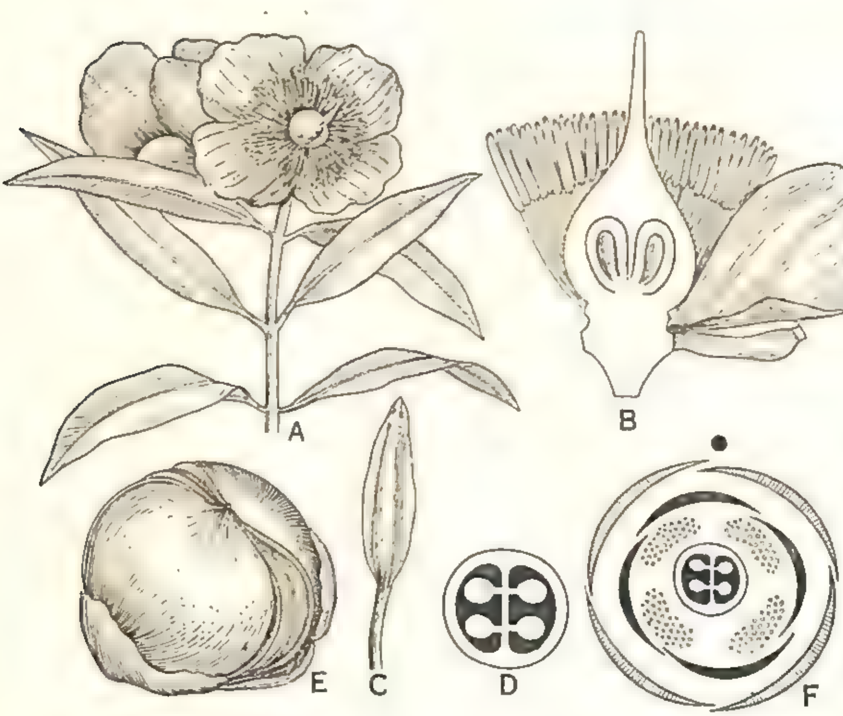


Fig. 607. Guttiferae (*Mesua ferrea*).
A, Portion of a flowering shoot; B, V.s. of the flower; C, Stamen; D, T.s. of ovary; E, Fruit; F, Floral diagram.

Common plants

(1) Cowa tree (*Garcinia cowa* Roxb.). (2) *G. xanthochymus* Hook. f. (3) Mangostene (*G. mangostana* L.), often planted in gardens for its delicious aril. (4) Alexandrian laurel (*Calophyllum inophyllum* L.), often grown in gardens as an avenue tree. (5) *Mesua ferrea* L., often planted in gardens for its fragrant flowers.

Affinity

This family bears close affinity with Theaceae and Dipterocarpaceae. From the study of floral morphology of various genera

with special reference to 4-merous arrangement of the perianth members, its relationship may be suggested with the members of the Parietales.

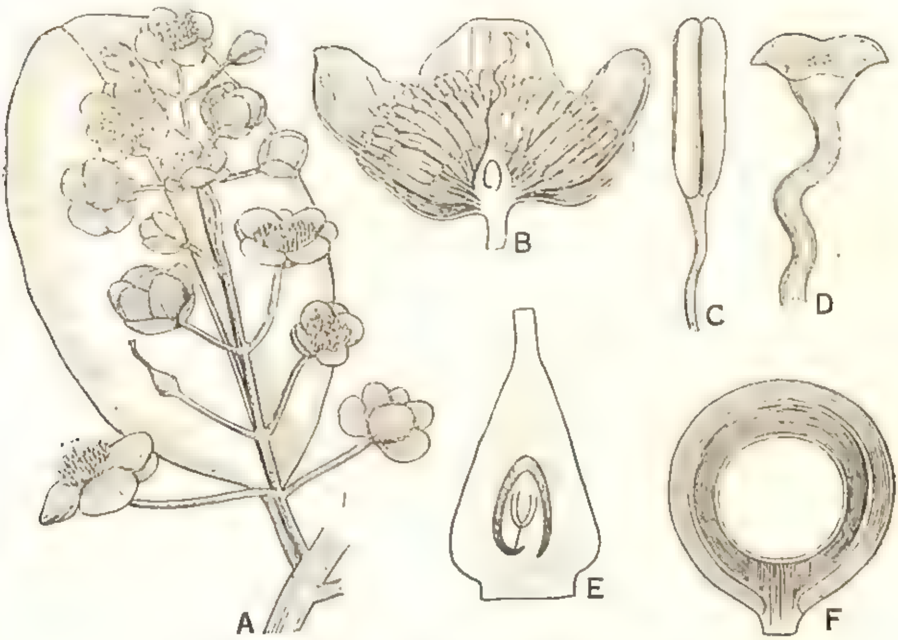


Fig. 608. Guttiferae (*Calophyllum inophyllum*).
A, Portion of a flowering shoot; B, V.s. of a flower; C, Stamen; D, Part of pistil; E, L.s. of ovary; F, T.s. of fruit.

Economic importance

This family is of little economic importance. The sweet-scented flowers of *Mesua ferrea* are used in perfumery. The wood of *Garcinia* is used as a timber. The seeds of *Allanbackia stahlmanni* yield oil. Gambage, the yellow pigment of commerce, is obtained from *Garcinia morella* Desr. *Garcinia mangostana* yields highly delicious fruits. Some plants are also cultivated as ornamentals, such as, *Garcinia*, *Mesua*, *Calophyllum*, etc.

DIPTEROCARPACEAE

General characters

Plants—usually huge trees with copious *resinous juice.* Leaves—alternate, simple, entire, coriaceous, stellately pubescent, stipulate

(convolute stipules). Inflorescence—raceme or panicle. Flowers—regular, bisexual, hypogynous. Sepals—5, united at the base forming 5 lobes, imbricate, *persistent* (in *Dipterocarpus* only two calyx-lobes grow out into wings, but in *Shorea* all five develop into wings). Petals—5, free, twisted. Stamens—numerous or less, free or slightly polyadelphous; connective often prolonged. Carpels—(3); ovary; superior, *3-celled with 2 pendulous ovules in each.* Fruit—*samara*, enclosed in the persistent sepals. Seed—exalbuminous, with straight or curved embryo.

Number and distribution

This family consists of 16 genera and 300 species which are commonly found in the tropics.

KEY TO GENERA

A. Calyx forming a distinct tube, 2 lobes accrescent and erect; fruit tree .. .. *Dipterocarpus.*

B. Calyx-tube short or rudimentary, segments subvalvate

- (*i*) 2 calyx-lobes winged; stamens 15; fruit a 3-valved coriaceous capsule or indehiscent; fls. in axillary panicles .. .. .. *Vatica.*
- (*ii*) calyx-lobes equal; stamens 16; anthers apiculate; fruit a capsule; fls. in axillary panicles .. *Isauxis.*

C. Calyx-lobes imbricate

- (*iii*) 3 or all segments enlarged in fruit, indehiscent; stamens 15-numerous, subulate or cuspidate .. *Shorea.*
- (*iv*) 2 calyx-segments enlarged; stamens 10-15, subulate or cuspidate .. .. .. *Hopea.*

Common plants

(1) Sal tree (*Shorea robusta* Gaertn.), a huge timber tree. (2) Garjan balsam (*Dipterocarpus turbinatus* Gaertn.), a gigantic tree commonly found in Eastern Pakistan (Chittagong and Tipperah). (3) *Isauxis lancaefolia* King, found in Chittagong. (4) *Vatica scaphula* Dyer., commonly occurring in Chittagong, can also be found in the Indian Botanic Garden. (5) *Hopea odorata* Roxb., a garden plant.

Affinity

This family resembles Guttiferae in possessing resin. It is also

allied to Magnoliaceae by the presence of large convolute stipules but readily distinguished by the enlarged persistent calyx.

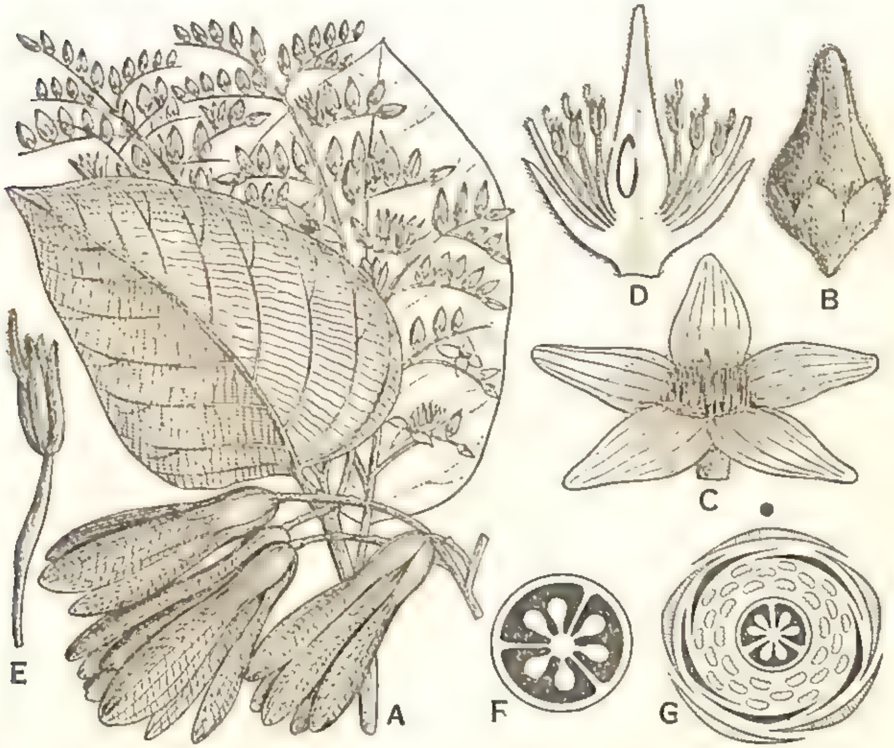


Fig. 609. Dipterocarpaceae (*Shorea robusta*).
A, Portion of a flowering shoot; B, Flower bud; C, Flower; D, V.s. of the same; E, Stamen; F, T.s. of ovary; G, Floral diagram.

Economic importance

This family is somewhat economically important. *Shorea* yields timber of great value and a resin, known as Dammar resin, much used as an incense. *Dipterocarpus* yields a liquid balsam or resin known as Garjan-oil.

VIOLACEAE

General characters

Plants—annual or perennial herbs. Leaves—usually alternate, simple, sometimes lobed, *stipulate*. Inflorescence—solitary (e.g.,

Viola) or terminal spike with bracts and bracteoles. Flowers—*irregular* or regular, bisexual, hypogynous, sometimes cleistogamous. Sepals—5, uniform in size or prolonged at the base (e.g., *Viola*),

Fig. 610. Violaceae (*Viola tricolor*).
A, Portion of a flowering shoot; B, Flower cut lengthwise; C, Pistil; D, T.s. of ovary; E, Young pistil; F, Stamen; G, Seed; H, Fruit; I, L.s. of a seed; J, Fruit; K, Floral diagram.

persistent, imbricate. Petals—5, of which the lowermost *one largest and spurred* or saccate, imbricate or twisted. Stamens—5, with short filaments, *introrse;* the *connective of anterior pair of anthers often*

spurred at the base in irregular flowers or otherwise appendaged in regular flowers, *forming a cone round the ovary*. Carpels—(3-5); ovary superior, 1-celled with 1-many anatropous ovules on 3 *parietal placentae;* style 1, terminal; stigma variable in shape. Fruit—*3-chambered capsule*, splitting elastically and loculicidally into 3 boat-shaped valves. Seed—ovoid or subglobose, albuminous with straight embryo.

Number and distribution

This family consists of about 16 genera and 850 species, widely distributed in temperate and tropical regions but chiefly in the warmer parts of the globe.

KEY TO GENERA

Sepals prolonged at the base	*Viola*.
Sepals not prolonged at the base	*Ionidium*.

Common plants

(1) Pansy (*Viola tricolor* L.) and (2) Sweet violet (*Viola odorata* L.) are common garden plants. (3) *Ionidium suffruticosum* Cing., a common small branching perennial.

Affinity

This family is distinguished from the allied families by the pentamerous flowers, stamens basally united and introrse, spurred corolla, and 3-chambered capsule fruit.

Economic importance

This family is of very little economic importance. Different species of *Viola* (*V. odorata*, *V. tricolor*, etc.) are ornamentals.

PASSIFLORACEAE

General characters

Plants—mostly tendril climbers, sometimes shrubs. Leaves—alternate, simple or compound, generally lobed, *stipulate*. Flowers—regular, bisexual (unisexual in *Modecca*), bracteate. Sepals

—usually 5, free or united at the base, persistent, imbricate. Petals —usually 5, often smaller than sepals, free, imbricate, *with corona.* Stamens—5, originally free but become *uplifted by androphore;* anthers 1-celled. Carpels—(3-5); ovary superior, often raised on a gynophore, 1-celled with many anatropous ovules on parietal placentae; styles 3-5, free or united at the base, each bears a capitate stigma. Fruit—*berry or capsule.* Seeds—*arillate with perisperm.* Embryo—straight.

Fig. 611. Passifloraceae (*Passiflora suberosa*).
A, Portion of a flowering shoot; B, Flower; C, V.s. of the same; D, T.s. of ovary; E, Floral diagram.

Number and distribution

This family consists of 11 genera and about 600 species which are chiefly found in the tropics.

A. Fls. bisexual, stamens hypogynous, plants usually twining herbs .. .. *Passiflora.*

B. Fls. unisexual

Corollas of male and female fls. similar; stamens perigynous; plants twining herbs or undershrubs .. *Modecca.*

Common plants

(1) Passion flower (*Passiflora foetida* L., *P. suberosa* L., *P. lunata* L.). (2) *Modecca cordifolia* Bl. and *M. palmata* Lam., very common.

Affinity

This family is closely allied to Cucurbitaceae from which it is readily distinguished by stipulate leaves, bisexual flowers with corona, gynandrophore, superior ovary and arillate seeds.

Economic importance

This family is domestically important for ornamentals, and for the production of edible fruits (e.g., *Passiflora edulis*, *P. ligularis*, etc.).

Fig. 612. Passifloraceae (*Passiflora foetida*).

ORDER 28. OPUNTIALES

Plants generally succulent with reduced leaves. Flowers bisexual, regular or irregular. Stamens numerous. Ovary inferior. Fruit berry.

According to Engler this Order contains only one family Cactaceae. Bentham and Hooker have placed Cactaceae in the cohort Ficoidales under the subclass Polypetalae. Hutchinson designated this Order as Cactales (31st Order) which contains a single family Cactaceae.

CACTACEAE

General characters

Plants—succulent herbs, usually with thick angular or flattened or cylindrical stems (phylloclades), which are simple or branched, and most of them have prominent vertical ridges and spines.

Leaves—usually modified into spines*, or sometimes developed and flat or cylindrical in shape but soon fall off. Flowers—regular or nearly so, bisexual (sometimes unisexual), epigynous. Perianth—numerous in *several series*, generally more or less united to form a tube, sometimes free. Stamens—numerous, epiphyllous, rarely arise from the thalamus. Carpels—(3-many); ovary *inferior*,

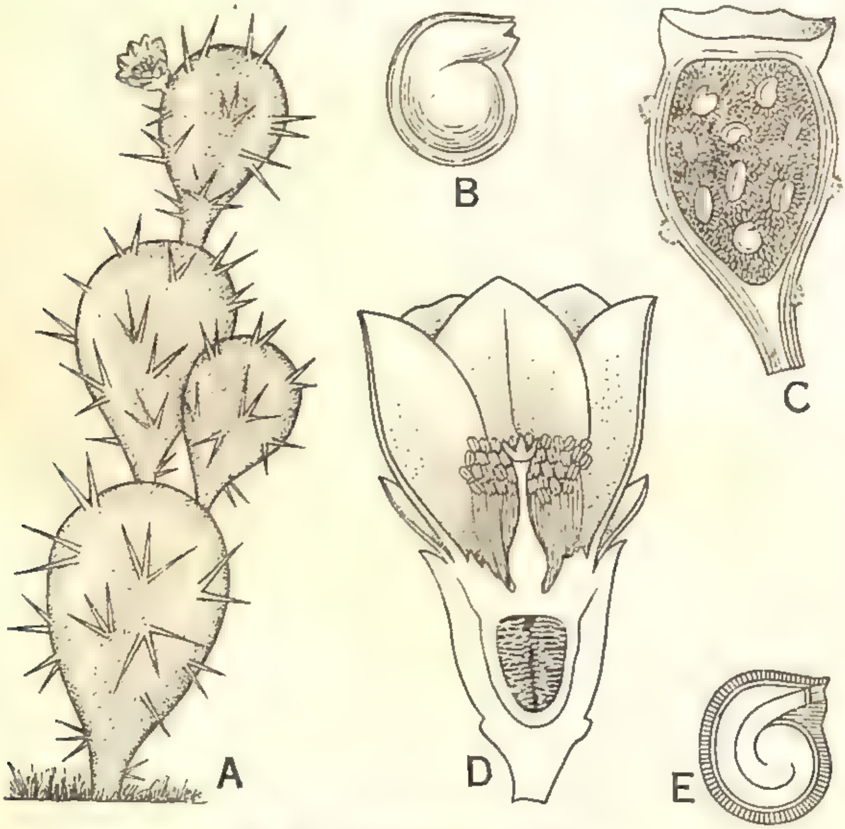


Fig. 613. Cactaceae (*Opuntia dilleni*).
A, A phylloclade bearing a flower; B, Seed; C, L.s. of a fruit; D, V.s. of a flower; E, L.s. of a seed.

1-celled with 3 or more *parietal placentae* bearing numerous anatropous ovules; style simple; stigma equal to the number of carpels. Fruit—berry, often glochidiate, spiny or bristly, many-seeded. Seed—usually exalbuminous, often with black testa. Embryo—straight or curved.

*Spines grow from rounded cushions or *tubercles* composed of a combination of leaf base and rudimentary branch.

Number and distribution

This family consists of about 130 genera and 1200 species which are typically xerophytic and widely distributed in the tropics.

Common plant

Prickly pear (*Opuntia dilleni* L.), a common xerophyte with phyllocade bearing numerous spines.

Affinity

This family is closely related to Loasaceae based on the floral plan and serological data as supposed by Carl Mez. According to Engler, it has been placed under Opuntiales, an Order supposed to have been originated from Parietales. Hutchinson and Bessey placed this family near Cucurbitaceae. Hallier, Wettstein and Maheswari (1945) and others suggest that this family should be transferred to a position within or near the Centrospermae, based on the characters of embryo, anatomy and floral morphology. Cactaceae is characterized by the fleshy habit with spines, solitary flowers with an undifferentiated perianth, numerous spirally arranged stamens and glochidiate berry.

Economic importance

This family is of domestic importance as it contains ornamentals, and they are extensively cultivated in Europe. The fruit of the Prickly pear (*Opuntia* sp.) is edible.

ORDER 29. MYRTIFLORAE

Plants herbs, shrubs or trees. Leaves opposite, simple, exstipulate. Flowers regular, bisexual, cyclic, perigynous to epigynous, generally tetra- or penta-merous. Stamens diplostemonous or obdiplostemonous. Pistil frequently oligomerous. Ovary multilocular to unilocular with numerous ovules on axile placentae. Seeds exalbuminous.

According to Engler this Order consists of 4 suborders containing 20 families, viz., Lythraceae, Rhizophoraceae, Combretaceae, Myrtaceae, Melastomaceae, Onagraceae, etc. Bentham and Hooker have placed the aforesaid families in the cohort Myrtales under subclass Polypetalae. In Hutchinson's system, Lythraceae and

Onagraceae have been put under the Order Lythrales (21st Order), while Myrtaceae, Melastomaceae, Combretaceae and Rhizophoraceae under the Order Myrtales (33rd Order).

LYTHRACEAE

General characters

Plants—trees, shrubs or herbs, often with square stems. Leaves—opposite or whorled, simple, entire, with or without minute

Fig. 614. Lythraceae (*Lawsonia alba*).
A, Portion of a flowering shoot; B, Flower; C, Pistil; D, T.s. of ovary; E, L.s. of the same; F, Floral diagram.

stipules. Inflorescence—raceme. Flowers—medium (e.g., *Lagerstroemia*) or minute (e.g., *Ammania*), regular (sometimes irregular e.g., *Cuphea*), bisexual, perigynous. Sepals—4-8, united into a tube, *valvate.* Petals—4-8, (sometimes absent e.g., *Peplis*), free, inserted at the mouth of the corolla, crumpled, usually with *crisped margins.* Stamens—usually twice as many as petals in 2 whorls, inserted on the calyx-tube, generally bent in bud. Carpels—(2-6); ovary superior, usually 2-6-celled with many anatropous ascending ovules in each on axile placentae. Fruit—*capsule.* Seed—exalbuminous. Embryo—large, usually straight with flat cotyledons.

Number and distribution

This family consists of about 23 genera and 475 species which are chiefly distributed in the tropics.

KEY TO GENERA

(*a*) Calyx membraneous; fls. minute; stem quadrangular, reddish; herbaceous	*Ammania.*
(*b*) Calyx curved; fls. scarlet; calyx-tube free from ovary ..	*Woodfordia.*
(*c*) Calyx straight; fls. symmetrical	
(*i*) 4-merous white fls.; branches often spinescent; capsule dehiscing irregularly	*Lawsonia.*
(*ii*) 6-merous fls., rarely 5-8-fid. strongly clawed petals; capsule 3-6-valved: seeds winged; leaves opposite ..	*Lagerstroemia.*
(*iii*) 4-8-fid fls.; petals clawed and crisped, adnate to conical ovary; capsule 4-8-valved; seeds minute ..	*Duabanga.*

Common plants

(1) The Henna plant (*Lawsonia alba* Lamk. = *L. inermis* L.), a common hedge plant. (2) *Lawsonia indica.* (3) Indian Lilac or

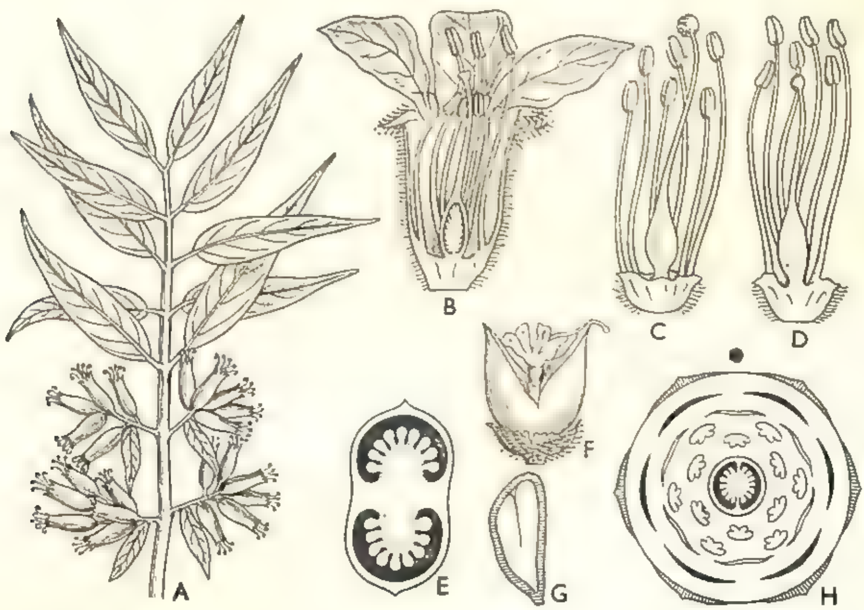


Fig. 615. Lythraceae (*Woodfordia floribunda*).
A, Portion of a flowering shoot; B, V.s. of a flower; C, Medium and short stamens with long stigma; D, Long and medium stamens with short stigma; E, T.s. of ovary; F, Fruit; G, L.s. of seed; H, Floral diagram.

Crape myrtle (*Lagerstroemia flos-reginae* Retz. = *L. speciosa* Pers.), a timber tree. (4) *Lagerstroemia thorellii* Gagnep., commonly planted on roadsides. (5) *Ammania baccifera* L., a common weed found on roadsides and wet places. (6) *Woodfordia floribunda* Salisb. = *W. fruticosa* Kurz., a common shrub with di- and tri-morphic flowers. (7) *Duabanga sonneratioides* Ham., occurs in North Bengal, also can be seen in the Indian Botanic Garden.

Affinity

This family is closely allied to Melastomaceae, Onagraceae, Saxifragaceae, and Myrtaceae but readily distinguished by the crumpled corolla, stamens twice the number of petals, superior ovary and exalbuminous seeds.

Economic importance

This family is economically important from the standpoint of ornamental value. Among the ornamental plants are *Lagerstroemia indica* and *Lawsonia inermis*, abundantly cultivated in the warmer countries of the world. Some species of *Cuphea* are also useful for decorative purposes. Species of *Lagerstroemia* yeild good quality of timber.

RHIZOPHORACEAE

General characters

Plants—trees or shrubs of salt swamps and marshes (halophytes), mostly with *pneumatophores*. Leaves—opposite, simple, *coriaceous*, persistent, stipulate or exstipulate. Inflorescence—cymose. Flowers—regular, bisexual (rarely unisexual), perigynous to epigynous, surrounded at the base by cup-like bracts. Sepals—3-14, more or less united at the base and adnate to the ovary, fleshy or leathery, persistent, valvate. Petals—as many as the sepals, generally smaller than the sepals, convolute. Stamens—usually twice as many as petals, situated on the outer edge of a lobed disc; filaments very short. Carpels—(2-4); *ovary inferior*, 2-5-*celled with 2 pendulous anatropous ovules* in each cell; stigma simple or lobed, usually persistent. Fruit—usually berry, sometimes capsule. Seeds—exalbuminous or albuminous, sometimes arillate. Embryo—straight, and often *green*, contains 3-4 cotyledons; the germination of seeds is marked with *vivipary*.

Number and distribution

This family consists of about 17 genera with 70 species. Many plants form characteristic components of the mangrove vegetation of muddy coasts and estuaries.

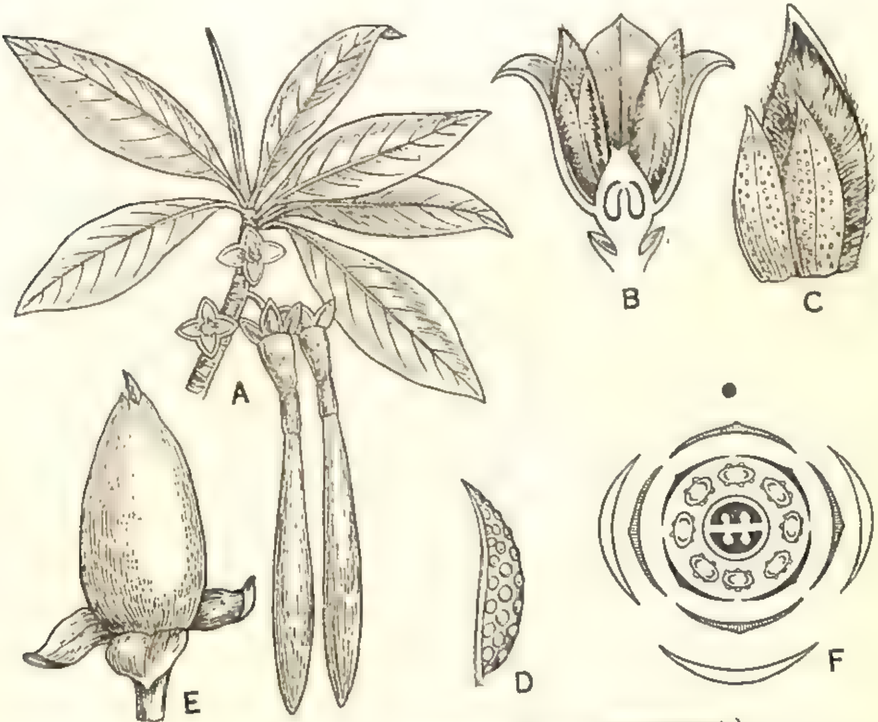


Fig. 616. Rhizophoraceae (*Rhizophora mucronata*).
A, Portion of a shoot with flowers and germinating seeds; B, V.s. of a flower; C, A petal with two opposite stamens; D, Stamen; E, Fruit; F, Floral diagram.

KEY TO GENERA

A. Sea-shore trees (mangrove); seeds exalbuminous; embryo with a large hypocotyl germinating while the fruit is still on the tree

(a) Calyx-segments and petals each 4; petals entire; stamens 8; ovary 2-celled .. .. .. *Rhizophora.*

(b) Calyx-segments and petals each 5-6; petals not entire;
Petals emarginate; stamens 10-12; ovary 3-celled .. *Ceriops.*
Petals lacerate; stamens infinite; ovary 1-celled .. *Kandellia.*

(c) Calyx-segments and petals 8-14; calyx without bracteoles; petals 2-fid; stamens 16-28; ovary 2-4 celled .. .. *Bruguiera.*

B. Inland trees; seeds albuminous; embryo not germinating till fruit falls; calyx-tube minutely bracteolate .. *Carallia.*

Common plants

(1) *Rhizophora mucronata* Lamk., a small evergreen tree found in the Sundribans. (2) *R. conjugata* L. = *R. candelaria* DC., a small tree. (3) *Ceriops roxburghiana* Arn., a large shrub of the Sundribans. (4) *Kandelia rheedi* W. & A., a small tree. (5) *Brugiera gymnorhiza* Lamk. = *B. conjugata* Merr., a large tree. (6) *Carallia lucida* Roxb., an evergreen tree with shining leaves.

Affinity

This family closely resembles Combretaceae and Myrtaceae, but is readily distinguished by the presence of pneumatophores, coriaceous leaves, numerous stamens, 2-5-celled ovary with 2 ovules in each cell, green cotyledons and viviparous germination of seeds.

Economic importance

This family is less importan. economically. Bark and foliage of some species produce tannin. The wood obtained from rhizophoraceous plants are used generally for piling and construction under water.

COMBRETACEAE

General characters

Plants—trees or shrubs, sometimes climbing. Leaves—usually alternate sometimes opposite, simple, exstipulate. Inflorescence—usually racemose (raceme, spike or panicle). Flowers—regular, bisexual (rarely unisexual by reduction), epigynous, tetra- or penta-merous, bracteate. Sepals—(4-5), persistent valvate, united at the base in a calyx-tube, adnate to the ovary and produced above it. Petals—small, 4-5, sometimes *0* (e.g., *Terminalia*, *Anogeissus*), inserted on the calyx-tube, imbricate. Stamens—4-5 *in* 1 *series, or* 8-10 *in* 2 *series*, inserted on the limb or tube of the calyx. Carpels—(4-5); ovary inferior, generally *angled*, 1-*celled* with 2-6 anatropous, pendulous ovules. Fruit—2-5 angled, drupaceous and indehiscent, often winged. Seed—exalbuminous with cotyledons spirally rolled or folded.

Number and distribution

This family consists of 18 genera with 500 species occurring in the tropical region.

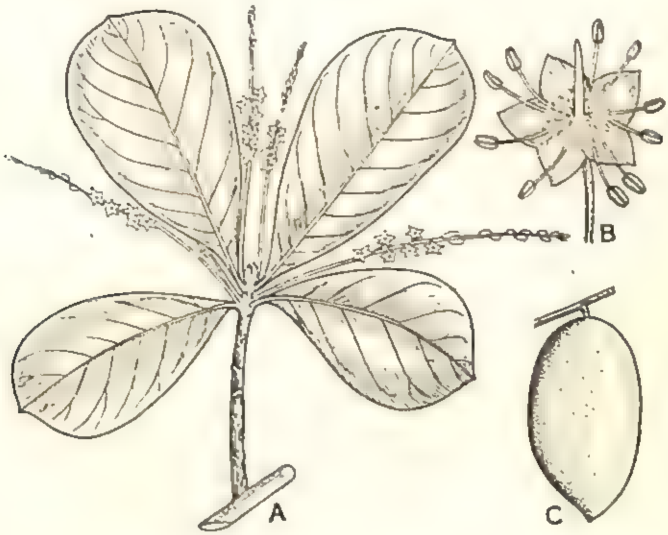


Fig. 617. Combretaceae (*Terminalia catappa*).
A, Portion of a flowering shoot; B, Flower; C, Fruit.

Key to Genera

A. Inflorescence racemose (raceme, spike or head); calyx-lobes valvate; stamens without glands or staminodes; ovules 2-4.

(*a*) Petals *O*

Calyx-limb deciduous; erect trees or shrubs

Flowers in heads .. .. .. *Anogeissus*.

Flowers in spikes or racemes .. .. *Terminalia*.

(*b*) Petals 5 or 4

(*i*) Calyx-limb deciduous; climbers with opposite leaves

Calyx-tube not or shortly produced beyond ovary .. .. *Combretum*.

Calyx-tube much produced beyond ovary .. *Quisqualis*.

(*ii*) Calyx-limb persistent; shrubs or trees with alternate leaves .. .. .. *Lumnitzera*.

B. Inflorescence cymose; calyx-lobes imbricate; stamens with glands or staminodes; ovule solitary .. .. *Gyrocarpus*.

Common plants

(1) *Anogeissus latifolia* Wall., a tree. (2) The Indian almond (*Terminalia catappa* L.) frequently cultivated. (3) Myrobolan (*T. chebula* Roxb.). (4) The Beleric myrobolan (*T. belerica* Roxb.). (5) *T. arjuna* W. & A., a common avenue tree, occasionally planted in gardens. (6) *T. tomentosa* W. & A., a large tree with villous twigs. (7) Rangoon creeper (*Quisuqalis indica* L.), a common climbing garden plant. (8) *Lumnitzera racemosa* Willd., a small tree found in the Sundribans. (9) *Gyrocarpus americana* Jacq., a large tree. (10) *Combretum decandrum* Roxb., a large shrub. (11) *Combretum ovalifolium* Roxb., a large climbing shrub.

Fig. 618. Combretaceae (*Quisqualis indica*).
A, Portion of a flowering shoot; B, V.s. of a flower; C, T.s. of ovary; D, Floral diagram.

Affinity

This family is closely related to Myrtaceae in the inferior ovary and number of perianth leaves, but readily distinguished by the number of stamens, 1-celled ovary with 4-6 pendulous ovules and drupaceous indehiscent fruit.

Economic importance

This family has little economic importance. The Indian

almond (*Terminalia catappa*) yields edible nuts. *Terminalia chebula*, the common myrobolan, is one of the important commercial products of India. Some plants are useful for timbers. Species of *Combretum* and *Quisqualis* are ornamentals.

MYRTACEAE

General characters

Plants—trees or shrubs. Leaves—usually opposite, simple, entire, exstipulate, coriaceous, *gland-dotted*, usually with *submarginal*

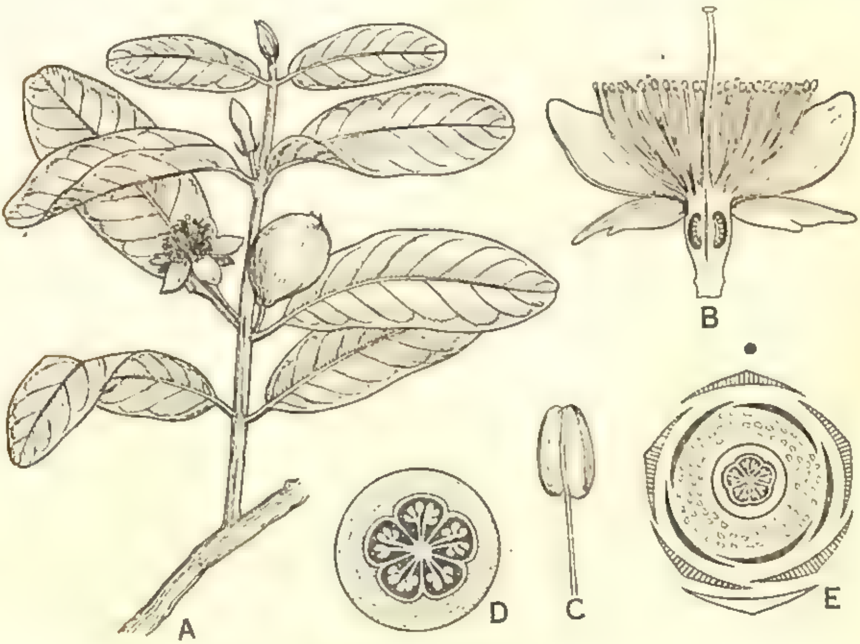


Fig. 619. Myrtaceae (*Psidium guyava*).
A, Portion of a flowering shoot; B, V.s. of a flower; C, Stamen; D, T.s. of ovary; E, Floral diagram.

veins. Inflorescence—cymose. Flowers—regular, bisexual, epigynous. Sepals—4-5 (but absent in *Eucalyptus*), usually free, sometimes more or less persistent or thrown up as a cup, quincuncial. Petals—4-5, free, inserted on a disc forming a lining to the calyx-tube, imbricate. Stamens—*numerous*, *free* or polyadelphous (e.g., *Melaleuca*), *bent inwards in bud*, inserted on the disc, with 2-celled anthers; connective often prominent and gland-tipped. Carpels—(2-5) or numerous; ovary *inferior*, 1-many-celled with 2-many ovules

situated on axile placenta; style long. Fruit—berry or capsule, tipped by calyx-limbs. Seeds—exalbuminous. Embryo—thick, often curved.

Number and distribution

This family consists of about 80 genera and 3000 species which are chiefly distributed in tropical regions.

KEY TO GENERA

A. Fruit capsule, bursting into valves: stamens numerous. slightly united below into antipetalous bundles; fls. in heads or spikes .. .. *Melaleuca.*

B. Fruit fleshy berry (indehiscent)

(*i*) Sepals subimbricate and closed in bud but become deeply cleft and valvate in opened fls.; fruit a berry with a crown of persistent calyx; seed reniform .. .. .. *Psidium.*

(*ii*) Sepals 4- or 5-lobed both in bud and flower; ovary 2-3-celled, with many ovules in each cell; seed globose or compressed .. .. *Eugenia.*

(*iii*) Sepals 4 or 5, connate in a turbinate tube, adnate to and scarcely produced beyond the ovary; ovary 2-4-celled with many irregularly or biseriately arranged ovules on the axis; seed subreniform .. .. .. *Myrtus.*

Common plants

(1) *Guava* (*Psidium guyava* L.), a small fruit-tree cultivated throughout India. (2) Black plum or Jambu (*Eugenia jambolana* Lamk. = *Syzium cumini* Skeels), a large fruit-tree. (3) Rose-apple (*Eugenia jambos* L. = *Syzium jambos* Alston), a small fruit-tree. (4) Malay-apple (*Eugenia malaccensis* L. = *Syzium malaccense* Merr. & Perry), another small fruit-tree. (5) Clove (*Eugenia caryophylloea* Wight = *Syzium caryophylla* Alston), cultivated in South India and Ceylon, yields cloves which are dried unopened flower buds. (6) *Melaleuca leucadendron* L., a native of Malacca Islands, yields the 'cajuput oil' of commerce. (7) *Eucalyptus globulus* Labille, cultivated throughout India which produces timber and an oil. (8) Myrtle (*Myrtus communis* L. = *Acmena communis* Merr. & Perry), a shrub of hedges. (9) Bottle brush tree (*Callistemon speciosus* L.), commonly planted in gardens.

Affinity

This family is closely allied to Rosaceae on the one hand and to Melastomaceae, Lythraceae and Onagraceae on the other, but

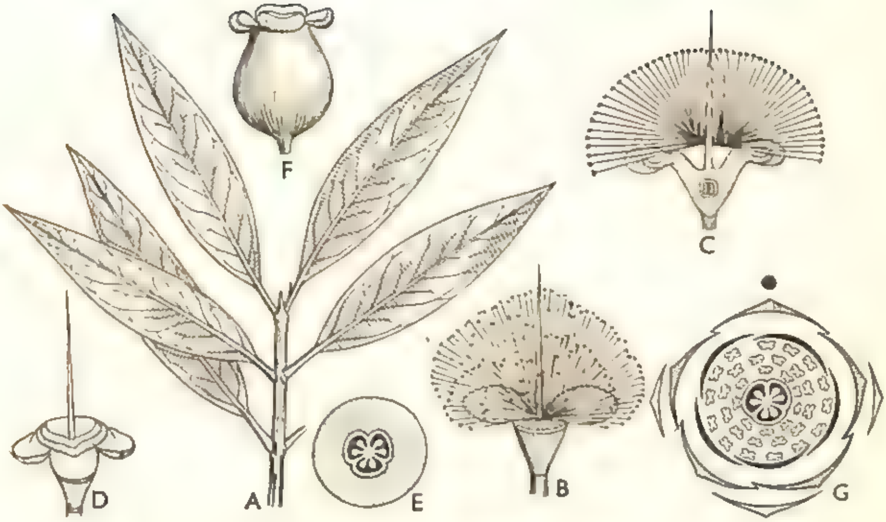


Fig. 620. Myrtaceae (*Eugenia jambos*).
A, Portion of a shoot; B, Flower; C, V.s. of the same; D, Pistil; E, T.s. of ovary; F, Fruit;, G, Floral diagram.

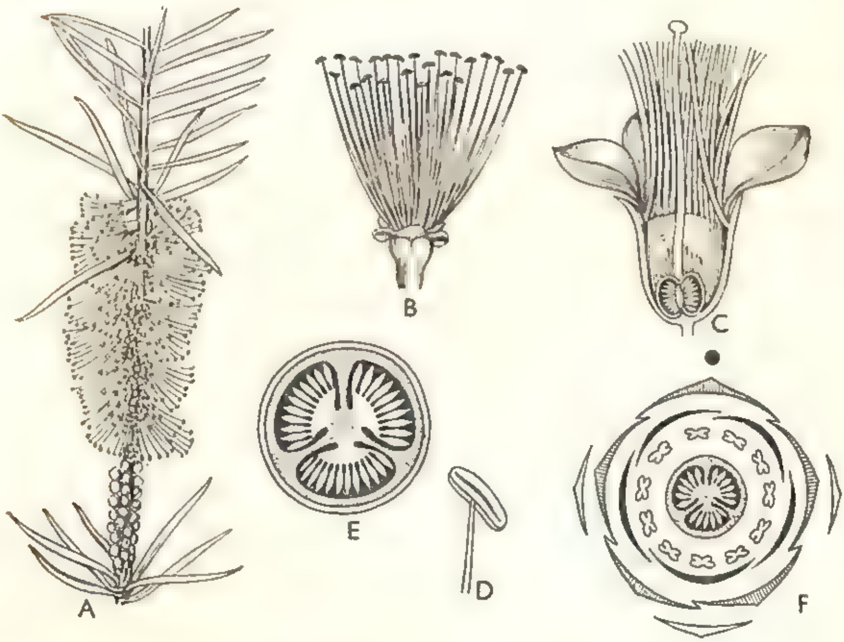


Fig. 621. Myrtaceae (*Callistemon speciosus*).
A, Portion of a flowering shoot; B, Flower after removal of calyx and corolla; C, V.s. of a flower; D, Stamen; E, T.s. of ovary; F, Floral diagram.

is readily distinguished by the opposite, gland-dotted leaves with submarginal veins, numerous stamens with gland-connectives and inferior ovary with axile placentation.

Economic importance

This family is of considerable economic importance. Most of the plants are cultivated chiefly for their edible fruits, such as guava, rose-apple, malay apple, black-plum, etc. *Melaleuca* yields the 'cajuput oil' of commerce. Leaves of *Eucalyptus* also yield an oil on distillation which is much used in medicine. Some other *Eucalyptus* yield valuable timber. The dried flower buds of *Eugenia caryophylloea* is known as clove, which is used as a spice. A few species are also cultivated as ornamentals, such as, *Eucalyptus*, the bottle brushes (*Callistemon* and *Melaleuca*), the lilly-pilly (*Acmena smithii*) and the myrtle (*Myrtus communis*).

MELASTOMACEAE

General characters

Plant—herbs or shrubs, sometimes small trees (e.g., *Memecylon*). Leaves—opposite, decussate, simple, entire, curvi-veined (*3-9-nerved*), exstipulate, often with stiff hairs. Inflorescence—cymose. Flowers—regular or slightly irregular, bisexual, peri- or epi-gynous. Sepals—5, free, sometimes united to form a cup or 0, valvate; calyx-tube often beset with stellate or dense tomen-

Fig. 622. Melastomaceae (*Osbeckia chinensis*).

tum. Petals—usually 5, free, *twisted*. Stamens—usually double the number of petals, and in two whorls, either all alike (e.g., *Osbeckia*), or alternately different in length and form (e.g., *Melastoma*); anthers long and linear, *beaked*, opening by apical pores and variously curved; filaments bent inwards. Carpels—(4-5); ovary usually inferior, sometimes superior, usually 4-5-celled with numerous anatropous ovules in each cell, style and stigma 1 and simple. Fruit—usually capsule or berry. Seed—exalbuminous, with minute embryo.

Fig. 623. Melastomaceae (*Tibouchina semidecandra*).
A, Portion of a flowering shoot; B, V.s. of a flower; C, Stamens (dimorphic); D, T.s. of ovary; E, Floral diagram.

Number and distribution

This family consists of about 150 genera and 4,000 species which are chiefly found in the hills.

Key to Genera

A. Fruit capsule; seeds many; ovary 4-5-celled; placentation axile; leaves 3- or more-nerved from base
  (*a*) Petals 4-5; seeds curved
    (*i*) Stamens all alike .. .. .. *Osbeckia.*
    (*ii*) Stamens unequal .. .. .. *Melastoma.*
  (*b*) Petals 3; seeds straight .. .. .. *Sonerila.*

B. Fruit berry; seeds solitary; ovary 1-celled; placentation free central; leaves pinnately nerved .. .. *Memecylon.*

Common plants

(1) *Melastoma malabathricum* L., commonly found from the foot of the Himalayas up to Darjeeling. (2) *Osbeckia chinensis* L., *O. nepalensis* Hook. and *O. crinita* Benth., common in the hills. (3) *Memecylon edule* Roxb. and *M. capitellatum* L. are small trees, can be found in the Indian Botanic Garden. (4) *Sonerila tenera* Royle, a herb. (5) *Tibouchina semidecandra* L., a common garden shrub.

Fig. 624. Melastomaceae (*Memecylon edule*).
A, Portion of a flowering shoot; B, Flower; C, Stamen; D, T.s. of ovary.

Affinity

This family is allied to Myrtaceae and Lythraceae but readily distinguished by 3-9-nerved leaves, valvate calyx, twisted corolla and beaked anthers.

Economic importance

This family is of little economic importance. Certain genera are important for ornamentals, such as, *Memecylon*, *Tibouchina*, *Medinella*, *Melastoma*, etc.

ONAGRACEAE

General characters

Plants—mostly annual or perennial herbs (occasionally aquatic e.g., *Jussiaea*), sometimes shrubs (e.g., *Fuchsia*). Leaves—opposite or alternate, always simple entire, exstipulate or stipulate (e.g., *Fuchsia*). Inflorescence—racemose (raceme or spike). Flowers

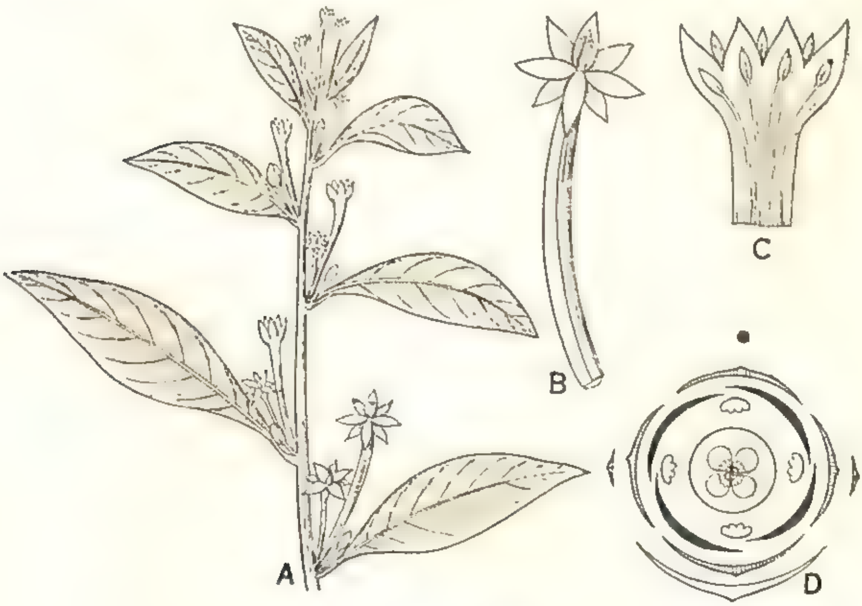


Fig. 625. Onagraceae (*Ludwigia parviflora*).
A, Portion of a flowering shoot; B, Flower; C, L.s. of the same; D, Floral diagram.

—usually regular, bisexual, epigynous, *tetramerous*, sometimes pentamerous (e.g., *Fuchsia*). Sepals—usually (4), but 6 in *Jussiaea*, tubular, adnate to the ovary and often extended far above it, valvate, persistent (e.g., *Ludwigia* and *Jussiaea*). Petals—usually 4 imbricate. Stamens—4 or 4+4, obdiplostemonous, rarely 6 (e.g.,

Jussiaea). Carpels—usually (4); ovary *inferior*, *usually 4-celled* with 1 to numerous anatropous ovules in each cell; style 1, slender. Fruit—a capsule or nut-like, sometimes berry (e.g., *Fuchsia*). Seed—exalbuminous. Embryo—straight.

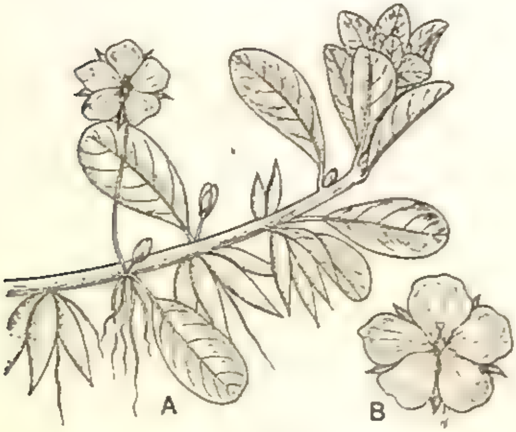


Fig. 626. Onagraceae (*Jussiaea repens*). A, Portion of a flowering shoot; B, Flower.

Number and distribution

This family consists of 20 genera with about 650 species widely distributed but mostly abundant in subtropical regions.

Fig. 627. Onagraceae (*Fuchsia hybrida*). A, Portion of a flowering shoot; B, V.s. of a flower; C, Floral diagram.

KEY TO GENERA

Seeds numerous; plants growing in swamps

(*i*) Stamens twice as many as the calyx-lobes .. .. *Jussiaea*.

(*ii*) Stamens equal in number to the calyx-lobes .. *Ludwigia*.

Common plants

(1) *Jussiaea repens* L., a herb commonly found creeping on the margins of tanks and floating on the surface of water. (2) *J. suffruticosa* L., a semi-shrubby erect perennial. (3) *Ludwigia parviflora* Roxb., an erect herb commonly found in rice fields. (4) *L. prostrata* Roxb., a prostrate herb found in rice fields. (5) *Fuchsia hybrida* L., a garden plant with handsome flowers, commonly found on the hills.

Affinity

This family is closely allied to Lythraceae but readily distinguished in having 4-merous flowers, inferior many-ovuled ovary, and exalbuminous seeds.

Economic importance

This family is of little economic importance. Some plants, such as, *Fuchsia* and others are ornamentals.

ORDER 30. UMBELLIFLORAE

Plants woody or herbaceous. Leaves alternate, often large with a sheathing base, exstipulate. Inflorescence generally umbellate, (simple or compound). Stamens episepalous. Carpels often reduced to two. Ovule solitary in each chamber, pendulous, anatropous. Seeds with copious endosperm. Oil or resin-passages often present.

According to Engler this Order consists of 3 families, viz., Araliaceae, Umbelliferae and Cornaceae. Bentham and Hooker have placed the family Umbelliferae in the cohort Umbellales under the subclass Polypetalae. This Order (59th Order) of Hutchinson contains 5 families.

UMBELLIFERAE

General characters

Plants—herbs with furrowed stems, usually with hollow internodes; schizogenous oil ducts present in the stems, roots and mostly

also among the mericarps; these are known as '*vittae*'. Leaves—alternate (but opposite in *Apiastrum*), often decompound, sometimes simple (e.g., *Hydrocotyle* and *Bupleurum*), with *sheathing leaf-bases*, exstipulate. Inflorescence—usually compound umbel, sometimes simple umbel (e.g., *Hydrocotyle*), subtended by involucel. Flowers—small, bisexual (sometimes unisexual), regular, epigynous. Sepals—5, free, often scarcely indicated. Petals—5, free, often unequal, with short claws, imbricate. Stamens—5, free, alternating with petals and arising from an epigynous disc. Carpels—(2), median, mostly prominently ribbed and often with parallel resinous canal; style 2, free but swollen at the base to form a *stylopodium;* ovary inserted on a disc, *inferior*, 2-celled with one pendulous ovule in each cell; stigma bifid. Fruit—*cremocarp* or *nut-like.* Seed—albuminous with minute embryo.

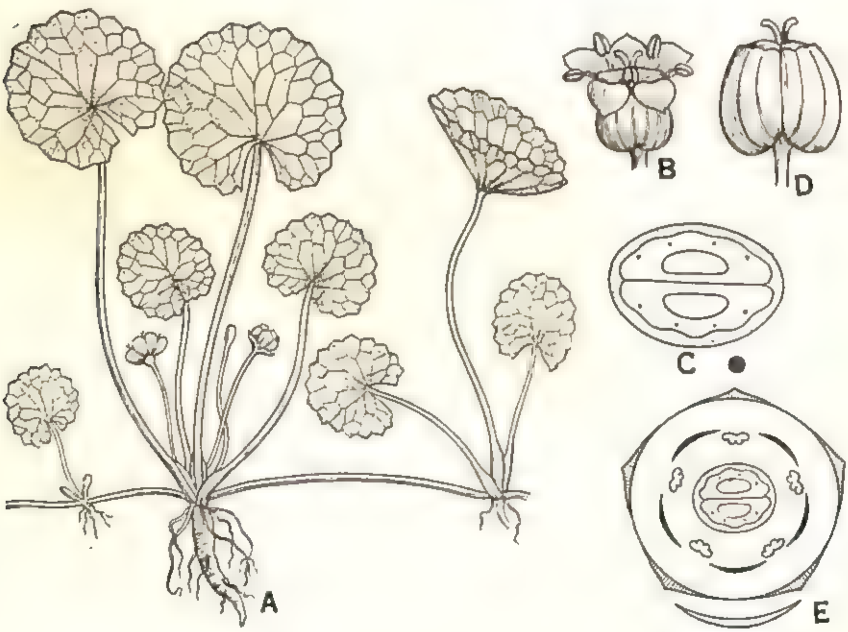


Fig. 628. Umbelliferae (*Hydrocotyle asiatica*).
A, Portion of a plant with flowers; B, Flower; C, T.s. of ovary; D, Fruit; E, Floral diagram.

Number and distribution

This family consists of about 200 genera and 2,900 species which are cosmopolitan but chiefly temperate, specially in the Northern hemisphere.

KEY TO GENERA

A. Leaves simple
  Umbels simple .. .. *Hydrocotyle.*
  Umbels compound .. .. *Bupleurum.*

B. Leaves compound
  (*a*) Secondary ridges of the fruit not prominent
    (*i*) Primary ridges not winged
      Flowers yellow, furrows of the fruit vittate .. *Foeniculum.*
      Flowers white—
        Furrows of the fruit 1-vittate
        Lobes of leaves linear, fruit ovoid, laterally compressed .. .. .. *Carum.*
        Each leaflet pinnate or partite, fruit not laterally compressed .. .. *Seseli.*
        Marshy herbs, leaves 1-3-pinnate, fruit longer than broad, carpophore 0 .. .. *Oenanthe.*
    (*ii*) Primary lateral ridges of the fruit excurrent, winged .. .. *Peucedanum.*
  (*b*) Secondary ridges of the fruit prominent
      Involucre of bracts none, fruits glabrous .. *Coriandrum.*
    Bracts of involucre numerous, pinnate, cultivated for its edible root, fruit hirsute .. .. *Daucus.*

Range of floral structures

The constant feature of this family is the presence of umbellate inflorescence. The most commonest form of inflorescence is compound umbel, but simple umbels do also occur, e.g., *Hydrocotyle* and *Astrantia*. Occasionally, the umbel is reduced to a single flower, as in species of *Hydrocotyle* and *Azorella*. In *Eryngium*, the flowers are aggregated into dense heads being enclosed by a whorl of bracts; again each flower is surrounded by a bract. The terminal flower is represented by the genus *Daucus*.

As a matter of fact, the floral development is very much astounding, because the stamens grow out first followed usually by petals and then by sepals. The presence of calyx is less perceptible. The two rudimentary carpels develop later on. Firstly they separate and become joined at their margins, whereas the stylopodium is formed by the roof.

Calyx is usually much smaller than the corolla, and they are represented by inconspicuous teeth being present on the upper

edge of the ovary. In *Eryngium*, *Astrantia*, *Sanicula* these structures are best developed; the sepals are with slight imbricate aestivation. The corolla is either with open, valvate or imbricate aestivation. The apex of corolla becomes sometimes pointed and the length of the point and the extent of inflexion in the bud give characters for recognition of different genera.

The aggregation of flowers into more or less dense inflorescences renders them conspicuous. The flowers in the circumference are often sterile (male) and become zygomorphic. The outer petals become much larger than the inner ones of the same flower and of the other flowers of the head. The flowers are usually white and sometimes become pink or yellow in colour, and very rarely they appear as blue.

The fruit is crowned by the ring of calyx and the remains of the styles, and finally divides into two carpels. Before falling, two mericarps often hang for a short period on a thin simple or bifurcated stalk, the *carpophore*. There are found great variations in the nature and structure of the mericarps and these variations ultimately provide characters for the identification of genera and larger groups.

This family has been divided into 3 subfamilies based on the characters of fruits:

(a) **Hydrocotyloideae:** The fruit is with a woody endocarp but with no free carpophore. Vittae (oil-glands) absent or sunk in the main ribs only.

(b) **Apioideae:** The endocarp is soft and parenchymatous but sometimes with subepidermal layers of wood fibres. Vittae are of various types; style on the apex of stylopodium.

(c) **Saniculoideae:** The endocarp is soft and parenchymatous, exocarp rarely smooth; style is surrounded by a ring-like disc (stylopodium).

Common plants

(1) Coriander (*Coriandrum sativum* L.). (2) Anise or Fennel (*Foeniculum vulgare* Gaertn.). (3) Ajowan (*Carum copticum* Benth. = *Trachyspermum amnia* Sprague). (4) *Carum roxburghianum* Benth. = *Trachyspermum burghianum* Craib. (5) Caraway (*Carum carui* L.). (6) Point caraway (*Cuminum cyminum* L.). (7) Carrot (*Daucus carota* L.). (8) *Peucedanum sowa* Kurz. = *Anethum sowa* L. (9) *Ferula asafoetida* Boiss. (10) Pennywort (*Hydrocotyle asiatica* L. = *Centella*

asiatica Urban), occurs as weed. (11) Celery (*Apium graveolens* L.), used as a vegetable. (12) Parsnip (*Pastinaca sativa*), also used as a vegetable. (13) *Bupleurum mucronatum* W. & A., occurs as a weed in the hills. (14) *Seseli indicum* W. & A., an annual much branched herb, common. (15) *Oenanthe bengalensis* Benth. and *O. stolonifera* Wall. = *O. javanica* DC., commonly found in moist shady places near ponds and ditches.

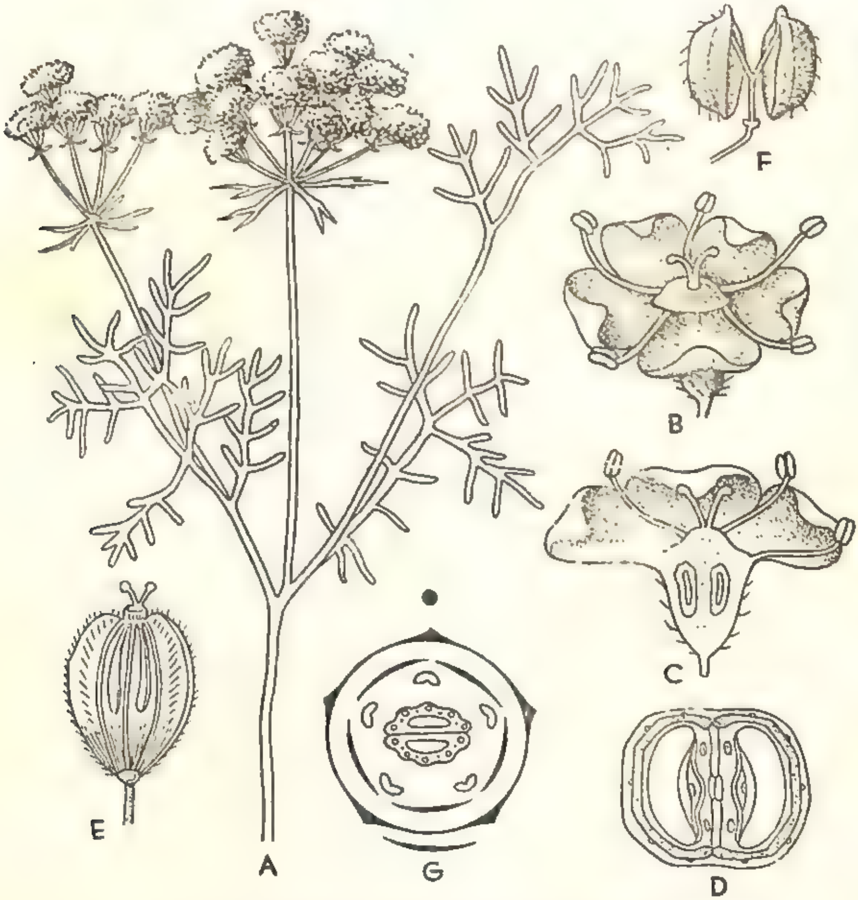


Fig. 629. Umbelliferae (*Coriandrum sativum*).
A, Portion of a flowering shoot; B, Flower; C, L.s. of the same; D, T.s of ovary; E, Fruit ; F, The same split open showing the carpophore; G, Floral diagram.

Affinity

This family recalls that of Compositae in the reduction of calyx, bicarpellate pistil, and two distinct styles, but readily distinguished

by the character of the fruit. It is also related to Rhamnales in the reduction of calyx, single staminal whorl, the prominent disc, and solitary ovule. Hutchinson has not kept Umbelliferae apart from Rhamnales. So according to him, a phylogenetic relationship can be drawn as such, Rhamnales → Umbelliferae → Compositae. Umbelliferae is readily distinguished from the allied families by the aromatic odour, sheathing leaf-base, umbellate inflorescence, pentamerous flower, 2-carpellate bilocular inferior ovary and cremocarp fruit.

Economic importance

This family is extremely important from domestic point of view. Various spices are obtained from plants, such as, *Foeniculum*, *Coriandrum* and *Carum*. Carrot (*Daucus carota*), celery (*Apium*), parsnip (*Pastinaca*), parsley (*Petroselinum*) are used as vegetables. Some plants are medicinal, such as, *Hydrocotyle* and *Peucedanum*. *Ferula* yields 'asafoetida' of commerce. Some plants are cultivated as ornamentals, such as, *Eryngium*, *Angelica*, *Heracleum*, *Aegopodium*, etc.

SUBCLASS 2. METACHLAMYDEAE (SYMPETALAE)

ORDER 4. EBENALES

Stamens usually in 2-3 whorls, epipetalous. Ovary septate at the base with 1 to few ovules on each of the axile placentae.

According to Engler this Order consists of 2 suborders containing 5 families, viz., Zapotaceae, Ebenaceae, etc. Bentham and Hooker have placed Zapotaceae in the cohort Ebenales under the subclass Gamopetalae. This Order (61st Order) in Hutchinson's system contains 2 families, viz., Ebenaceae and Zapotaceae.

ZAPOTACEAE

General characters

Plants—trees or shrubs with milky latex, the young twigs have woolly coverings. Leaves—alternate, simple, entire, coriaceous, exstipulate or stipulate. Inflorescence—cymose in the axils of leaves or on old stems. Flowers—regular, bisexual, hypogynous. Sepals—(4-12), the lobes subequal or the inner larger, imbricate. Petals—as

many as or 2-4 times as many as the calyx-lobes, united into a tube shorter than the calyx. Stamens—usually in 2 or 3 whorls of 4-5 each, but usually only the inner whorl fertile, others reduced to staminodes, epipetalous. Carpels—(4-5): ovary superior, 4-5-celled with 1 anatropous ascending ovule in each cell, integument one; style simple; stigma not prominent. Fruit—berry. Seeds—with hard shining testa; endosperm oily.

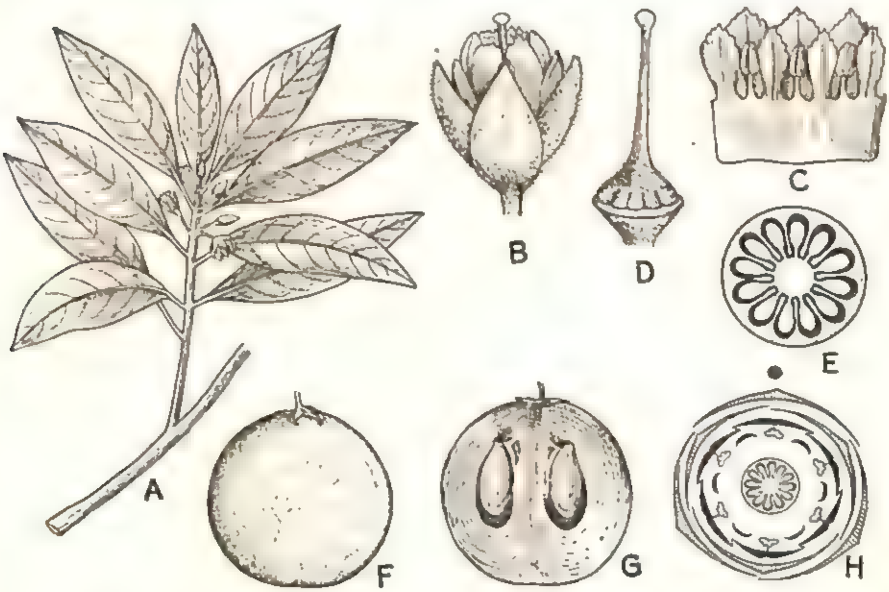


Fig. 630. Zapotaceae (*Achras sapota*).
A, Portion of a flowering shoot; B, Flower; C, Corolla-tube split open; D, Pistil; E, T.s. of ovary; F, Fruit; G, L.s. of the same; H, Floral diagram.

Number and distribution

This family consists of about 40 genera and 600 species. They are widely distributed in the tropics.

Key to Genera

A. Corolla-lobes and calyx-lobes equal in number:

(*a*) Calyx-segments in 1 series only; parts of fls. in whorl of 5; stamens as many as petals; staminodes as many as stamens and alternating with them; seeds exalbuminous

(*i*) Fls. sessile in branched panicles; ovary glabrous, cells 1-2 .. .. *Sarcosperma.*

(*ii*) Fls. pedicellate in axillary fascicles; ovary villous: cells 4-5 .. .. *Sideroxylon.*

(*b*) Calyx-segments in 2 distinct series; parts of flowers in whorls of 6.

(*i*) Stamens as many as petals; staminodes as many as stamens and alternating with them; ovary cells as many as petals; seeds albuminous .. .. *Achras.*

(*ii*) Stamens as many as petals; staminodes 0; ovary cells as many as petals; seeds exalbuminous .. *Dichopsia.*

Fig. 631. Zapotaceae (*Mimusops elengi*).
A, Portion of a flowering shoot; B, Corolla-tube split open; C, Fruit.

B. Corolla-lobes more numerous than calyx-lobes; ovary cells as many as calyx-lobes

(*a*) Staminodes 0; stamens about 2-3 times as many as corolla-lobes, in 1-3 series; corolla 8-14; calyx-lobes and ovary-cells 4 or 6; seeds exalbuminous .. *Bassia.*

(*b*) Staminodes 6 or 8; stamens also 6-8, fewer than the corolla-lobes; corolla-lobes 18-24 in 2-3 series; calyx-lobes and ovary-cells 6 or 8; seeds albuminous .. *Mimusops.*

Common plants

(1) *Sarcospermum arboreum* Hook. f., a large tree with spreading branches. (2) *Sideroxylon tomentosum* Roxb., a large tree. (3) The Sapota or Sapodilla plum (*Achras zapota* L.), a medium tree cultivated for edible fruits. (4) The Mahua (*Bassia latifolia* Roxb. = *Madhuca indica* Gmel.), a common tree. (5) *Mimusops elengi* L. and *M. hexandra* Roxb. = *Manilkara hexandra* Dub., are trees often planted in gardens for fragrant flowers. (6) *Dichopsis pentaphylla* Hook. f., a tree.

Fig. 632. Zapotaceae (*Bassia latifolia*).
A, Portion of a flowering shoot; B, Corolla-tube split open; C, Calyx; D, Stamen (front and back view); E, T.s. of ovary; F, Fruit.

Affinity

This family is related to Ebenaceae in the habit and structure of fruit but differs from it in having the completely septate superior ovary, each loculus containing a single ascending ovule having a single integument, and presence of milky latex.

Economic importance

This family is economically useful. The fruits of some species

are edible, such as, *Achras zapota* (the sapodilla plum), *Mimusops elengi*, etc. The wood of *Sideroxylon* is very stiff and yields valuable timber, often known as Iron wood. The bark of some species is frequently used in medicine. *Mimusops*, *Payena* and *Palaquium* yield latex, which is a source of guttapercha of commerce. The waxy flowers of *Bassia latifolia* produce a kind of country liquor, while the seeds yield a kind of oil, known as 'vegetable butter', chiefly used for adulterating ghee.

ORDER 5. CONTORTAE

Plants herbs, shrubs or trees. Leaves generally opposite, simple or pinnately compound, exstipulate. Flowers bisexual, regular, hypogynous. Corolla gamopetalous, lobes twisted. Stamens epipetalous, nectar-secreting disc present. Carpels 2, connate or free below, but united by the styles. Ovules few to many on parietal or axile placentae.

According to Engler this Order consists of 2 suborders containing 5 families, *viz.*, Oleaceae, Loganiaceae, Gentianaceae, Apocynaceae, Asclepiadaceae. Bentham and Hooker have placed the aforesaid families in the cohort Gentianales under the subclass Gamopetalae. There is no such Order in Hutchinson's system. He has put Oleaceae and Loganiaceae under the Order Loganiales (64th Order), Apocynaceae and Asclepiadaceae under the Order Apocynales (65th Order) and Gentianaceae under the Order Gentianales (68th Order).

OLEACEAE

General characters

Plants—shrubs, sometimes climbing (e.g., *Jasminum*) or trees (e.g., *Olea*, *Linociera*, etc.). Leaves—usually opposite, simple, or pinnately compound, entire or toothed, exstipulate. Inflorescence—cymose, usually 3-chotomous cyme. Flowers—regular, usually bisexual, hypogynous. Sepals—(4-5), small, valvate. Petals—(4-5), sometimes free or *O*, *mostly imbricate*. Stamens—*usually 2*, inserted on corolla-tube. Carpels—(2); ovary superior, 2-celled, usually with 2 *pendulous or ascending anatropous ovules* in each cell; style simple; stigma 1-2. Fruit—capsule (e.g., *Syringa*), berry (e.g., *Ligustrum*)

or drupe (e.g., *Olea*, *Linociera*, etc.), sometimes samara (e.g., *Fraxinus*). Seed—with abundant *fleshy endosperm*. Embryo—straight.

Number and distribution

This family consists of 22 genera and about 500 species which are distributed from the temperate to the warmer regions.

KEY TO GENERA

(*a*) Corolla-lobes imbricate, more than 4 in number

(*i*) Fruit a didymous berry, 2- or 1-lobed; seeds single, erect, rarely 2 in each cell; fls. in 2- or 3-chotomous or simple cymes; plants usually erect or suberect shrubs with simple or compound leaves .. *Jasminum*.

(*ii*) Fruit a compound capsule; fls. in bracteate heads of 3-chotomous cymes; seeds orbicular, erect, stigma shortly 2-fid .. .. *Nyctanthes*.

(*b*) Corolla-lobes valvate never exceeding 4 in number; fruit a drupe; shrubs or trees

(*iii*) Petals shortly united or sometimes absent; leaves with feathered leaf-veins; fls. in axillary panicles; seeds pendulous with fleshy albumen ... .. *Olea*.

(*iv*) Petals showy, free or united, induplicate; seeds solitary, pendulous, exalbuminous .. .. *Linociera*.

Range of floral structures

The flowers are usually small and they form compound raceme, as in *Ligustrum* and *Fraxinus*, while the flowers in *Jasminum nudiflorum*, remain united together in threes at the end of a shoot bearing scale. The flowers are generally axillary to bract and a pair of bracteoles are found to be present.

The flowers are usually bisexual but unisexual flowers occur in *Fraxinus* and in some species of *Olea*.

The calyx is obliterated in *Fraxinus excelsior* and others. If calyx is found, it is tetramerous, sometimes the 5th sepal occurs in the species of *Jasminum*.

The number of petals is equal to the number of sepals and alternate with the latter. The aestivation is valvate in *Syringa* or imbricate in *Jasminum*. The petals become free or united in the genus *Fraxinus*. *Jasminum nudiflorum* has 6 petals. The corolla is generally tubular or rotate with its flattened limbs, as in *Olea*, *Ligustrum*, and *Jasminum*.

The stamens are generally 2 and transverse but occasionally they are median. Sometimes 4 stamens occur in the monotypic genera *Hesperella* and *Tessarandra*, and these alternate with petals.

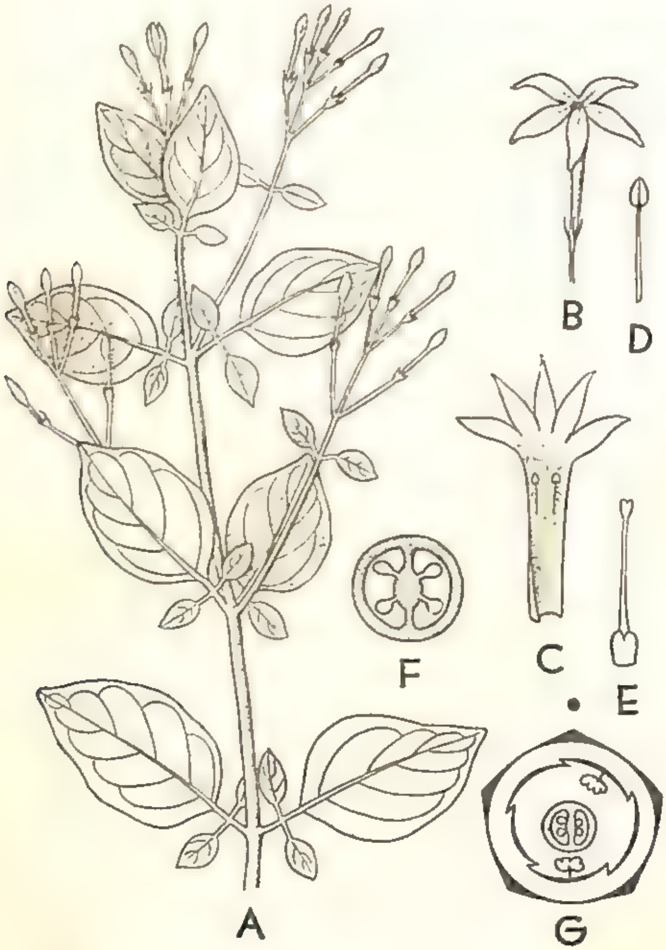


Fig. 633. Oleaceae (*Jasminum auriculatum*).
A, Portion of a flowering shoot; B, Flower; C, Corolla split open; D, Stamen; E, Pistil; F, T.s. of ovary; G, Floral diagram.

Two carpels are found to alternate with the stamens and they are generally median. The chamber of ovary becomes sometimes three to four. The ovules are generally 2 in each chamber, pendulous or ascending on axile placenta. One ovule is also sometimes found to occur.

Common plants

(1) Arabian Jasmine (*Jasminum sambuc* Ait.). (2) *Jasminum auriculatum* Vahl. and *J. grandiflorum* are commonly cultivated in gardens. (3) *Jasminum pubescens* Willd. (4) Night flowering jasmine (*Nyctanthes arbor tristis* L. – *J. multiflorum* Andr.), often planted in gardens. (5) Privet (*Ligustrum robustum* Bl.), a tree found in Eastern Pakistan and Assam. (6) *Olea dioica* Roxb., a tree 30-60 ft. high, chiefly found in North Bengal. (7) *Linociera ternifolia* Wall., a tree.

Affinity

According to Hutchinson this family is also allied to Melastomaceae. Some phylogenists consider this family to be related to Loganiaceae. It is allied to Rubiaceae and Apocynaceae but distinguished by the typically 2-merous flowers, aestivation of corolla, number of stamens, and 2-celled superior ovary with 2 ovules in each cell.

Economic importance

This family is of great economic importance. *Olea europea* yields edible fruits and is the source of olive oil of commerce. Ash lumber (*Fraxinus*) produces a valuable cabinet work. The corolla of *Nyctanthes* yields an orange dye. Some plants are ornamentals, such as, Privet (*Ligustrum*), Jasmine (*Jasminum*), fragrant Olive (*Osmanthus*), Lilac (*Syringa*), etc.

GENTIANACEAE

General characters

Plants—generally annual or perennial herbs, often with dichotomous branching. Leaves—usually opposite and decussate, sessile, simple, entire, 3-5-nerved, exstipulate. Inflorescence—cymose, often dichasial. Flowers—regular, bisexual, hypogynous, bracteate. Sepals—(4-5), tubular, persistent, imbricate. Petals—(4-5), tubular, rotate or salver- or funnel-shaped, twisted. Stamens—4-5, epipetalous, alternating with corolla-lobes. Carpels—(2); ovary superior, generally 1-celled (rarely 2-celled owing to the projection of two *parietal placentae* towards the centre) with numerous anatropous ovules; style simple; stigma simple or bilobed. Fruit—capsule. Seed—small with fleshy perisperm. Embryo—minute.

Number and distribution

This family consists of 70 genera and about 800 species which are chiefly found on the hills in temperate and tropical regions.

KEY TO GENERA

Style short, leaves opposite or rarely alternate

- (*i*) Corolla tubular-campanulate, without pits or depression; twiners .. .. .. *Crawfurdia.*
- (*ii*) Corolla-lobes twisted, with pits at the base .. *Swertia.*
- (*iii*) Corolla-lobes twisted clockwise; stigma divided; fls. irregular; minute herbs .. .. *Hoppea.*
- (*iv*) Stigmas 2 .. .. *Canscora.*
- (*v*) Corolla-lobes induplicate-valvate in bud; aquatic floating herbs with opposite leaves .. *Limnanthemum.*

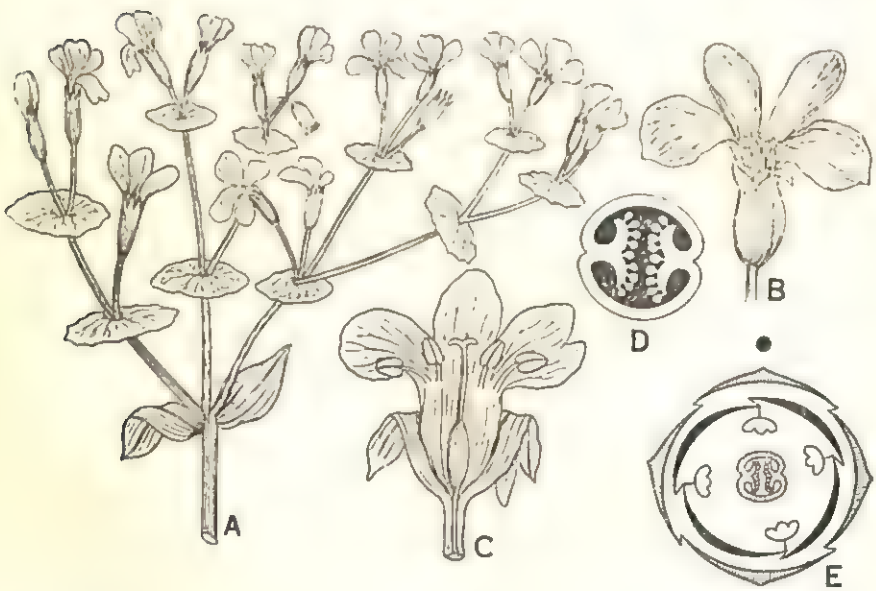


Fig. 634. Gentianaceae (*Canscora diffusa*).
A, Portion of a flowering shoot; B, Flower; C, L.s. of the same; D, T.s. of ovary; E, Floral diagram.

Common plants

(1) *Swertia chirata* Ham. grows in Darjeeling and other hilly places and is of great medicinal importance; *S. bicalyculata* L., a very common weed on the hills. (2) *Canscora decussata* R. & S. has amplexicaul leaves. (3) *Canscora grandiflora* Weight, has perfoliate

bracts. (4) *Canscora diffusa* R. Br., a dichotomously branched herb with connate leaves. (5) Snowflake (*Limnanthemum cristatum* Griseb.), a floating herb with white flowers, very common in tanks. (6) Gentian (*Gentiana lutea* L.), a medicinal plant. (7) *Hoppea dichotoma* Willd., a small much-branched, glabrous herb.

Affinity

This family is allied to Apocynaceae and Loganiaceae but readily distinguished from them by the nature of placentation, completely coherent carpels and absence of milky latex. Hutchinson has removed it from Loganiales and placed under the Order Gentianales near the Primulales. This family also bears a close link with Caryophyllaceae basing on the nature of inflorescence and mode of branching.

Economic importance

This family is of little economic importance. *Gentiana*, *Swertia* and *Canscora* are used in medicine. Some plants are used as ornamentals, such as, *Gentiana*, *Exacum*, *Menyanthes*, *Nymphoides*, etc.

APOCYNACEAE

General characters

Plants—trees, shrubs, herbs or woody climbers (e.g., *Beaumontia*, *Ichnocarpus*, *Aganosma*, etc.) with *milky latex*. Leaves—usually opposite and decussate, simple, entire, *exstipulate*. Inflorescence—cymose or racemes passing into cymes. Flowers—regular, bisexual, hypogynous, bracteate. Sepals—(5), often glandular, imbricate. Petals —(5), usually salver- or funnel-shaped (but bell-shaped in *Allamanda*), the *throat or interior of the tube often with hairs, scales or other outgrowths* (corona), *twisted*, rarely valvate. Stamens—5, epipetalous, almost sessile in the corolla-tube or throat of corolla; anther often *sagittate*; filaments very short. Carpels—2, completely united or *united by their styles and free below*; ovary superior, 1- or 2-celled with few to many anatropous, generally pendulous, ovules on the partition walls; stigma often thickened and *dumble-shaped*. Fruit—usually a *pair of follicles*, sometimes drupe or berry or capsule. Seeds—often flat, *winged or comose*, with bony or fleshy endosperm. Embryo—straight, nearly as long as the seed with flat, seldom folded, cotyledons.

Number and distribution

This family consists of about 300 genera and 1,300 species which are chiefly found in the tropical and subtropical regions.

I. Corolla-lobes overlapping to the left; anthers included, free from the stigma; anther-cells round at the base.

A. Calyx eglandular

(i) Carpels 2, syncarpous; ovary 2-celled with axile ovules; fruit large, fleshy or pulpy within; seeds wingless or with pencil of hairs; spiny shrubs .. .. *Carissa.*

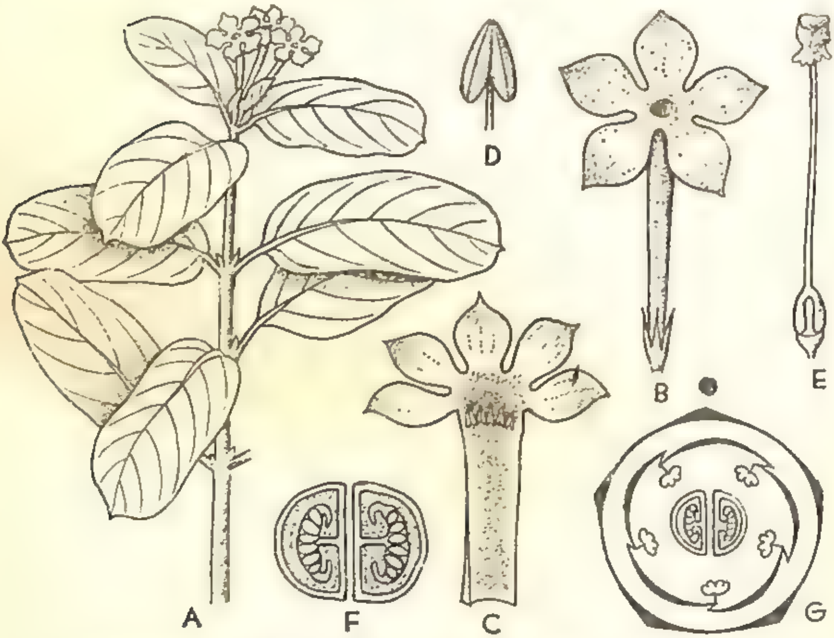


Fig. 635. Apocynaceae (*Vinca rosea*).
A, Portion of a flowering shoot; B, Flower; C, Corolla split open; D, Stamen; E, Pistil; F, T.s. of ovary; G, Floral diagram.

(ii) Carpels 2, wholly united; corolla salver-shaped; ovary 1-celled with parietal ovules; indehiscent ft.; seeds without albumen; climbing .. .. *Willughbeia.*

(iii) Carpels 2, united by the style; fruit various, rarely a pair of follicles; seeds peltate, winged; trees with alternate leaves .. .. *Plumiera.*

(iv) Carpels 2, thoroughly distinct or united, style calyptriform at the base, bifid at the top; fruit usually a double berry; disc present; undershrubs .. *Rauwolfia.*

(v) Corolla-lobes long, yellow or white; fruit a drupe; leaves whorled .. .. *Thevetia*

B. Calyx glandular, carpels 2, distinct

(a) Disc present

(i) Fruit a product of 2 ripe carpels, usually 1 abortive; leaves opposite; corolla salver-shaped; shrubs .. .. *Kopsia.*

(ii) Stigma annulate, viscid, sometimes with reflected membrane; ovules 6-many; follicular fruit with truncated seeds, subcylindric; herbs .. *Vinca.*

(iii) Fruit 2 slender follicles; style filiform; seeds comose; disc various or absent; leaves whorled; trees .. .. *Alstonia.*

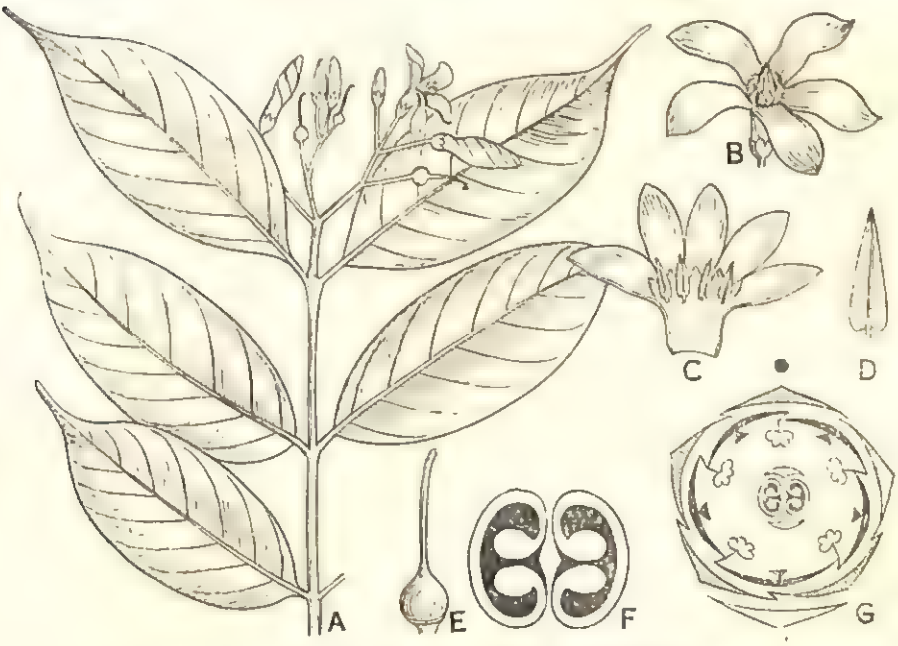


Fig. 636. Apocynaceae (*Wrightia tomentosa*).
A, Portion of a flowering shoot; B, Flower; C, Corolla split open; E, Pistil; F, T.s. of ovary; G, Floral diagram.

(b) Disc absent

(iv) Corolla tubular; style short; fruit 2 elongated follicles; seeds comose; leaves membraneous; trees .. .. *Holarrhena.*

(v) Corolla salver-shaped with cylindric slender tube; fruit of 2 reniform or oblong-ovoid ribbed seeds, buried in scarlet pulpy aril, compressed; stamens sagittate; leaves opposite; shrubs .. .. *Tabernaemontana.*

(*vi*) Corolla rotate or salver-shaped; mouth of corolla with a ring of scales; anthers conniving in a cone around the top of the style and attached to it by a point on the connective; carpels free except at the styles; erect shrubs or small trees .. *Wrightia.*

II. Corolla-lobes overlapping to the right; anthers included or exserted; anther-cells conniving in a cone around the top of the style.

Corolla-throat broad with 5-10 scales, fruit 2 follicles

(*i*) Lobes short with 5 broad scales; fruit elongate, erect follicles; seed villous, oblong; leaves whorled; shrubs .. .. .. *Nerium.*

(*ii*) Lobes long or tailed, with 10 scales; fruit elongate, hard, spreading; seeds compressed, fusiform; leaves opposite; shrubs or climbers .. *Strophanthus.*

(*iii*) Lobes long, with 10 scales; fruit a pair of hard follicles; fls. showy, white or purple; leaves opposite; climbers .. .. .. *Roupellia.*

(*iv*) Lobes large, mouth naked, disc deeply 5-lobed; fruit long, woody, dividing into 2 horizontally spreading follicles; climbers .. .. *Beaumontia.*

(*v*) Lobes long, mouth naked, yellow or violet; fruit capsule; leaves whorled or opposite; climbers .. *Allamanda.*

(*vi*) Lobes straight or slightly twisted to the left in the bud; disc cupular, 5-lobed; fruit follicular, straight or curved; seeds with deciduous coma; leaves opposite; climbers .. .. *Aganosma.*

(*vii*) Lobes short, twisted to the left in the bud; ovary hidden within the disc; seeds beaked, narrowed at the apex; leaves opposite; climbers .. *Ichnocarpus.*

Common plants

(1) Oleander (*Nerium odorum* Soland. = *N. indicum* Mill.), a common garden shrub. (2) Periwinkle (*Vinca rosea* L. = *Lochnera rosea* Reichb.), a common garden herb and also garden escape. (3) *Thevetia neriifolia* Juss. = *T. peruviana* Merr., common in gardens and also garden escape. (4) *Tabernaemontana coronatia* = *Ervatamia divaricata* Burhill, a cultivated garden shrub. (5) Natal plum (*Carissa carandas* L.), a spinous shrub cultivated for its acid berries. (6) Devil tree (*Alstonia scholaris* R. Br.), a tall tree with whorled leaves. (7) The Pagoda or Temple tree (*Plumiera acutifolia* Poir. = *P. rubra* L.), a small-sized tree found everywhere and very seldom fruits in our country. (8) *Ichnocarpus frutescens* R. Br., a much branched large

twining shrub. (9) *Aganosma caryophyllata* G. Don. = *A. dichotoma* K. Schum., very common in Bengal. (10) *Willughbeia edulis* Roxb., a climbing shrub with peduncles modified into tendrils. (11) *Holarrhena antidysenterica* Wall., a wild tree, the bark of which

Fig. 637. Apocynaceae (*Holarrhena antidysenterica*).
A, Portion of a flowering shoot; B, Flower; C, Calyx split open showing glands at the bases of sepals; D, Corolla split open; E, Pistil; F, T.s. of ovary; G, Fruit; H, Seed; I, Floral diagram.

is used in dysentery. (12) *Kopsia fruticosa* DC., a large evergreen shrub frequent in gardens. (13) *Allamanda cathartica* L., a climbing shrub in gardens. (14) *Rauwolfia serpentina* Benth. and *R. canescens* L. are medicinal plants found in shady waste places. (15) *Roupellia*

grata Wall., a climber in gardens. (16) *Beaumontia grandiflora* Wall., a lofty climber, often planted in gardens. (17) *Wrightia coccinea* Sims. and *W. tomentosa* Roem & Schult., small trees commonly planted in gardens. (18) *Strophanthus combe* DC., yields the 'strophanthus' of allopathic medicine. (19) *Dyera latifolia* Hook. f., *Urceola elastica* Roxb. and *Ecetinos achinthes mucronata* are rubber-producing plants.

Fig. 638. Apocynaceae (*Nerium odorum*).
A, Portion of a flowering shoot; B, Corolla split open; C, Stamen; D, Pistil; E, T.s. of ovary; F, Floral diagram.

Affinity

This family is closely allied to Asclepiadaceae from which it is readily distinguished by the freedom of stamens from the stigma, granular pollen and aestivation of corolla. In some respects it resembles Loganiaceae and Gentianaceae. Hallier included Apocynaceae with Asclepiadaceae and considered them to be derived from Linaceae.

Economic importance

This family is domestically important. Some plants, such as, *Alstonia*, *Holarrhena* and *Stropanthus* are most important from medicinal standpoint of view. *Carissa* yields edible fruits. The economic plants are *Dyera latifolia*, *Urceola elastica* and *Ecetinos achinthes*

mucronata, which yield rubber. Some plants are ornamentals, such as, *Nerium*, *Vinca*, *Carissa*, *Allamanda*, *Plumiera*, *Thevetia*, *Ervatamia*, etc.

ASCLEPIADACEAE

General characters

Plants—perennial herbs or shrubs, or woody climbers (e.g., *Dregea*, *Finlaysonia*, etc.), with milky latex. Leaves usually opposite and decussate, simple, entire, usually exstipulate. Inflorescence—cymose or racemose. Flowers regular, bisexual, hypogynous, *gynandrous*, either petals or stamens or both may bear appendages of various forms forming a single or double corona. Sepals—(5), very deeply lobed, quincuncial. Petals (5), generally rotate, sometimes campanulate or salver-shaped or funnel-shaped, twisted, rarely valvate (e.g., *Dregea*). Stamens—5, usually *adnate to the pistil forming a gynostegium; filaments united into a hollow column enclosing the style;* pollen grains united into 1 or 2 *pollinia* in each anther-lobe (in subfamily Cynanchoideae) or remain in tetrads (in sub-family Periplocoideae); the pollinia usually being united in pairs to a gland (*retinaculum*) on the 5-angular stigma and covered by a membrane (cf. Orchidaceae). Carpels—2, *united only by their styles and free below;* ovary superior with numerous, anatropous and pendulous ovules situated on the ventral suture; styles 2, cohering above and dilating to form a flat, 5-angular or lobed stigmatic head. Fruit—of 2 *follicles*. Seed—comose, with bony endosperm and large embryo.

Number and distribution

This family consists of 280 genera and about 1,800 species which are chiefly tropical.

Key to Genera

A. Filaments free; anthers acute or appendicular; pollinia granular, in pairs in each cell
 (*a*) Coronal scales corolline, free, short, thick; seeds with coma
  (*i*) Corolla small, rotate, lobes valvate .. *Hemidesmus.*
  (*ii*) Corolla small, rotate, lobes overlapping .. *Cryptolepis.*
  (*iii*) Corolla large, funnel-shaped, lobes overlapping .. *Cryptostegia.*

(*b*) Coronal scales filiform, 5, free, close to or adnate to the filaments

Corolla-lobes short and broad; filaments without intervening glands; seeds without coma; fls. in pubescent stout cyme .. .. .. *Finlaysonia*.

B. Filaments connate; anthers with membraneous tips inflexed; pollinia waxy, single in each cell, sessile or pedicelled in pairs, usually pendulous

(*c*) Coronal appendages double, outer coralline and inner staminal, with ligulate scales

Corolla wide rotate-campanulate, angularly 5-lobed; plant usually a twiner .. .. .. *Oxystelma*.

Corolla campanulate; processes of inner corona free from smooth staminal tube .. .. *Cynanchum*.

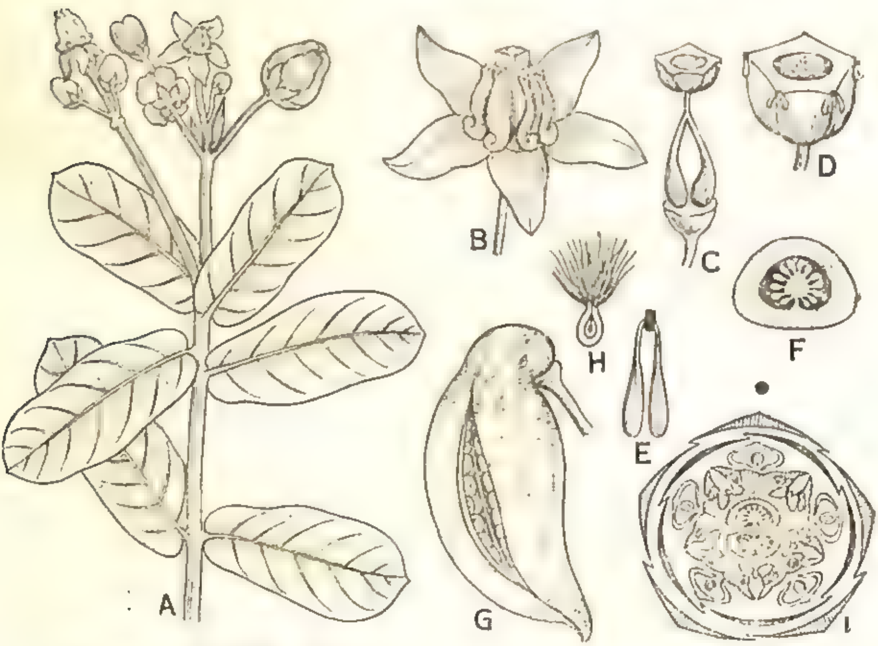


Fig. 639. Asclepiadaceae (*Calotropis procera*).
A, Portion of a flowering shoot; B, Flower; C, Pistil; D, Stigmatic head; E, Pollinia; F, T.s. of ovary; G, Fruit; H, Floral diagram

(*d*) Coronal appendages single (or while double both are staminal)

(*i*) Corolla wide campanulate; staminal corona radiating and laterally compressed, spurred on the back; plant erect .. .. .. *Calotropis*.

(*ii*) Corolla rotate; coronal processes staminal, spoon-shaped; ligulate at the face .. .. *Asclepias*.

(*iii*) Corolla twisted, rotate; outer coronary scales cupular, membraneous and the inner ones erect with a dorsal ligulary processes connecting the anthers .. .. *Sarcostemma.*

(*e*) Coronal appendages or only corona suppressed

(*i*) Corolla rotate, outer corona absent or rudimentary with larger or only lobes opposite the anthers .. .. *Pentatropis.*

(*ii*) Corolla funnel-shaped: outer corona conspicuous, 5-10-lobed, laterally compressed: stem twining .. *Daemia.*

(*iii*) Corolla campanulate, twisted, lobes short; corona *O*; stem twining .. .. *Sarcolobus.*

(*iv*) Corolla funnel- or salver-shaped; coronary scales erect or rarely absent; climbing shrub .. *Stephanotis.*

(*v*) Corolla campanulate or salver-shaped; coronal scales on the back of the anthers, simple .. *Marsdenia.*

(*vi*) Corolla rotate or salver-shaped; coronal scales on the back of the anthers, notched; fls. yellow or orange .. .. *Pergularia.*

(*vii*) Corolla rotate; coronal processes fleshy; stamens originating from the throat of the corolla-tube *Tylophora.*

(*viii*) Corolla rotate, green; coronal scales spreading in stellate processes, fleshy and thick; fls. in pendulous umbel .. .. .. *Dregea.*

(*ix*) Corolla rotate; coronal processes large; stellate anthers occasionally without membraneous tip *Hoya.*

(*x*) Corolla urceolate; scales of corona erect, membraneous .. .. *Dischidia.*

Range of floral structures

The plan of the flower is remarkably uniform with three regularly alternating pentamerous whorls of sepals, petals and stamens respectively and a bicarpellary pistil crowning the axis. The corolla is usually divided forming a rotate structure but the tube sometimes becomes longer, forming a salver-shaped corolla, as in *Stephanotis*, or pitcher-form corolla, as found in *Ceropegia.* Flowers are generally regular, but zygomorphic flower is found in *Ceropegia.* There are often found great variations in the form of corona-like petaloid appendages which arise just from the back of the stamens or at times from the corolla.

The shapes of the flowers are generally small; but relatively large flowers are found in *Ceropegia*, *Stapelia* and *Stephanotis.*

The five stamens and two carpels have separate origin on the floral axis. The ovaries are generally apocarpous, but the styles uniting to form a swollen stigma-head. It may become flattened, or more or less conical, or beaked.

The anthers are united laterally to form a 5-sided blunt cone which remains attached to the stigma-head. This sort of union of anthers and pistil forms a structure, known as *gynostegium.*

This family has been divided into 2 subfamilies based on the pollen structure. The first subfamily is **Periplocoideae,** characterized by the presence of granular pollen tetrads and translators spoon-shaped provided with an adhesive disc. Examples – *Hemidesmus*, *Cryptolepis*, etc. The second subfamily is **Cynanchoideae,** characterized by the pollens aggregated in 2-4 wax-like bodies known as pollinia. It contains the following genera, each has different pollinia construction. In genera *Asclepias* and *Calotropis*, pollinia are two in each anther, i.e., 10 in all ; in *Secamone* and *Genianthus*, the pollinia are four in each anther, i.e., 20 in all; in genera, such as, *Tylophora* and *Dregea*, pollinia two in each anther but erect. In genus *Gonololus*, the pollinia are in pairs in each anther but transverse.

Common plants

(1) *Calotropis procera* R. Br., a shrub with purplish flower growing throughout the plains of India. (2) *Calotropis gigantea* R. Br. (3) Indian Sarsaparilla (*Hemidesmus indicus* R. Br.), a twining shrub. (4) Milkweed or Silk weed (*Asclepias acida* Roxb. = *Sarcostema acidum* Voigt.). (5) *Asclepias curassavica* L., an erect perennial herb found in gardens and waste places near villages. (6) *Finlaysonia obovata* Wall. = *F. maritima* Backer, a large climbing plant found in Sundribans. (7) *Sarcolobus globosus* Wall., another climbing plant found in Sundribans. (8) *Cynanchum callialata* Ham., a twining shrub. (9) Wax-plant (*Hoya parasitica* Wall.), a twining epiphyte bearing wax-like leaves and flowers. (10) *Daemia extensa* Br. = *Pergularia daemia* Chois., a common climbing plant with spinous follicles. (11) *Dischidia rafflesiana* Wall., a stout twiner with pitchers 2-5 inches long, commonly found in Assam. (12) *Cryptostegia grandiflora* R. Br., a large stout climber in gardens. (13) *Pentatropis microphylla* W. & A., a slender twining herb, can be found from the salt lakes southwards to Sundribans. (14) *Dregea volubilis* Benth. = *Marsdenia volubilis* T. Cooke, a stout tall climber. (15) *Sarcostemma brevistigma*

Wight., grows wild. (16) *Tylophora asthmatica* W. & A. = *T. indica* Merr., a slender twining herb, very common. (17) *Oxystelma esculentum* R. Br., a climbing perennial herb. (18) *Cryptolepis buchanani* R. & S., common in hedges and village-shrubberries. (19) *Pergularia minor* Andr. = *Telosnia minor* Craib., a glabrous twining undershrub of gardens. (20) *Marsdenia tenacissima* W. & A., very common.

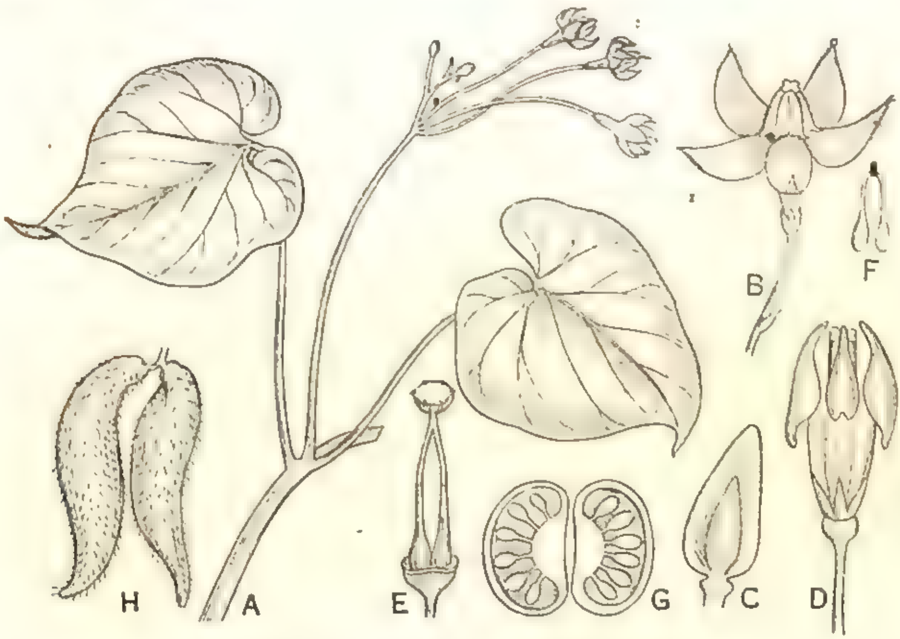


Fig. 640. Asclepiadaceae (*Daemia extensa*).
A, Portion of a flowering shoot; B, Flower; C, Petal; D, Flower with sepals and petals removed; E, Pistil; F, Pollinia; G, T.s. of ovary; H, Fruit.

Affinity

This family bears an affinity with families, such as Oleaceae, Loganiaceae, Gentianaceae and Apocynaceae in the characters of aestivation, in the form and shape of calyx and the number of carpels, but readily distinguished from them by gynandrous flowers, valvate corolla, presence of pollinia and gynostegium.

Economic importance

This family is of economic importance. Some plants, such as, *Hemidesmus*, *Calotropis*, etc., have medicinal properties. Some species of *Asclepias* are deadly poisonous. The Ceylon milk plant

(*Gymnema lactiferum*) is used as an article of food. Rubber is obtained from *Cryptostegia grandiflora*. A few genera are also used as ornamentals, such as, *Asclepias*, *Hoya*, *Stapelia*, *Periploca*, *Ceropegia*, *Cryptostegia*, etc.

ORDER 6. TUBIFLORAE

Plants generally herbs, sometimes woody. Leaves alternate or opposite, simple. Flowers typically bisexual, regular or zygomorphic, hypogynous, rarely epigynous, tetracyclic. Petals induplicate-valvate in bud. Stamens 4, epipetalous. Ovary bicarpellary and two- or one-celled, rarely 3-5 carpellary with as many cells. Ovules many to few in each cell on marginal placentation, each with a single integument.

According to Engler this Order consists of 7 suborders containing 20 families, *viz.*, Convolvulaceae, Boraginaceae, Verbenaceae, Labiatae, Solanaceae, Scrophulariaceae, Bignoniaceae, Pedaliaceae, Lentibulariaceae, Acanthaceae, etc. Bentham and Hooker have placed 17 families in 3 cohorts under series Bicarpellatae of the subclass Gamopetalae. Rendle has divided the Order into 4 suborders which include 17 families. There is no such Order in Hutchinson's system of classification. Boraginaceae has been placed under the Order Boraginales (73rd Order), Solanaceae and Convolvulaceae under the Order Solanales (74th Order), Scrophulariaceae, Bignoniaceae, Pedaliaceae, Lentibulariaceae and Acanthaceae under the order Personales (75th Order), and Verbenaceae and Labiatae under the Order Lamiales (76th Order).

CONVOLVULACEAE

General characters

Plants—usually annual or perennial herbs, often twiners (twining to the left), sometimes erect (e.g., *Cressa cretica*) or leafless parasites (e.g., *Cuscuta*), with watery latex. Leaves—alternate, simple, entire, or pinnately or palmately lobed. Inflorescence—dichasium or racemose (e.g., *Porana*), exstipulate. Flowers—regular, bisexual, hypogynous, bracteate. Sepals—5, usually free, quincuncial, often persistent. Petals—(5), usually *funnel-* or *salver-shaped*, *twisted*. Stamens—5, *unequal*, epipetalous, inserted at the base of the

corolla tube and alternating with petals; pollen ellipsoid or round. Carpels -(2); ovary superior, often surrounded by a disc, usually 2-celled with 2 *erect anatropous ovules*, or sometimes 4-celled with one anatropous ovule in each cell; style 1 (but 2 in *Cressa* and *Cuscuta*); stigma terminal and most frequently bilobed. Fruit —usually *capsule*, sometimes berry (e.g., *Argyreia, Cuscuta*). Seed—smooth or hairy, exalbuminous. Embryo—curved with *folded green cotyledons* (e.g., *Ipomoea*), or without cotyledons, or very rudimentary ones (e.g., *Cuscuta*), radicle directed towards hilum.

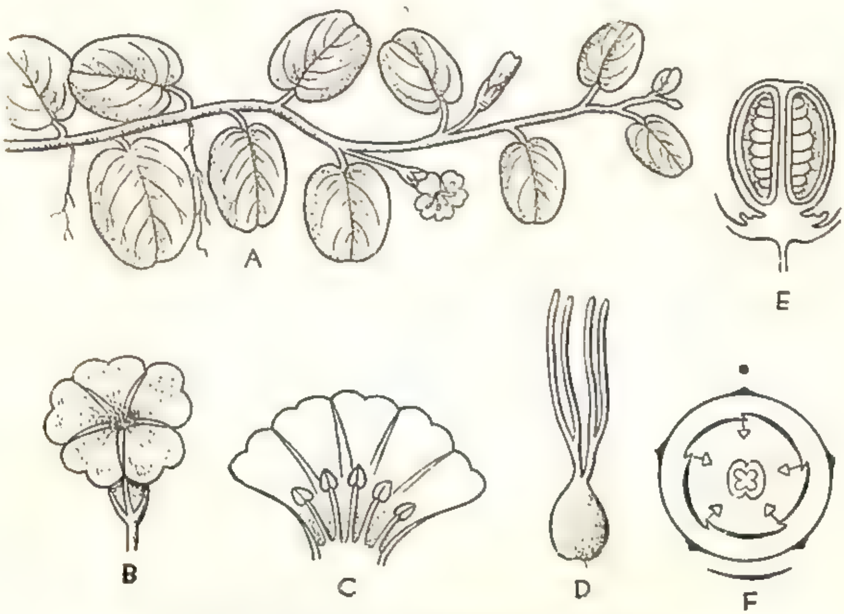


Fig. 641. Convolvulaceae (*Evolvulus nummularius*).
A, Portion of a flowering shoot; B, Flower; C, Corolla split open; D, Pistil; F, Floral diagram.

Number and distribution

This family consists of about 50 genera and 1,200 species, which are chiefly found in tropical and subtropical regions.

KEY TO GENERA

A. Corolla tube usually enlarged uniformly from base to apex, the 5 bands on the lobes not well-marked, pollen not spinescent

(*a*) Yellow parasites without leaves .. .. *Cuscuta*.

(*b*) Large climbers; flowers white, blue or purple; handsome garden plants .. .. .. *Porana*.

(*c*) Flowers in cymes or solitary; plants small, erect or diffuse annual, grey, pubescent .. .. *Cressa.*

(*d*) Climbing herbs: leaves cordate or elliptical: flowers blue, pink or white in umbellate or capitate cymes; ovary 2-locular; fruit capsule, hairs 3-many branched; garden plants .. .. *Jacquemontana.*

(*e*) Prostrate herbs or undershrubs; inflorescence is a few-flowered or solitary cyme; 2-carpels united by the ovaries only; fruit a 4-valved capsule, 2-1-locular; stigmas borne on the style arms .. .. *Evolvulus.*

(*f*) Twining herb; leaves cordate: fls. axillary, solitary or in a few-flowered cymes; bracts not enveloping the calyx; ovary 1-locular; ft. capsule, 4-valved 3-seeded; pollen polyhedral .. .. *Hewittia.*

B. Corolla tube hot uniformly enlarged from base to apex, bands on corolla-lobes prominent, pollen spinescent

(*a*) Fruit dehiscent

(*i*) Stamens arising direct from corolla

Corolla campanulate, inflorescence never scorpioid, stamens not exserted .. .. *Ipomoea.*

(*ii*) Stamens exserted

Flowers small, pink or white, slightly irregular *Quamoclit.*

Flowers large, white or purple, quite regular .. *Calonyction.*

(*b*) Fruit indehiscent, woody or mealy or fleshy

(*i*) Fruit woody; corolla salver-shaped; stigma elliptic-oblong .. .. .. *Rivea.*

(*ii*) Fruit mealy or fleshy, corolla rarely or not salver-shaped:

(1) Sepals large, orbicular, accrescent, ultimately completely enveloping the fruit .. *Stictocardia.*

(2) Sepals small, ovate, not enlarging to envelop the fruit:

Ovary 2-celled .. .. .. *Lettsomia.*

Ovary 4-celled .. .. .. *Argyreia.*

(3) Sepals unequal, outer 3 not larger than the inner 2; carpels 2; style entire; stigma globose; ovary 2-celled; bands of corolla demarcated by purple lines .. .. *Merremia.*

Common plants

(1) *Ipomoea reptans* Poir. = *I. aquatica* Forsk., an aquatic herb with very long-jointed, hollow stem. (2) Moon flower (*Ipomoea bona-nox* L. = *Calonyction bona-nox* Boj.), a large climber with white

flowers, opening at sunset. (3) Sweet potato (*Ipomoea batatas* Lamk. =*Batatas edulis*), a creeping herb with edible tuberous root. (4) *Ipomoea paniculata* R. Br. =*Jacquimontea paniculata* Hall. f., a medicinal plant with palmatisect leaves. (5) *Ipomoea pes-tigridis* L., a twining hairy plant with white or pale pink flowers, very common on waste places. (6) *I. hederacea* Jacq., a slender climber with pink or blue flowers, very common in waste places near villages during the rainy season. (7) Morning glory (*Ipomoea pulchella* Roth.), a very common twiner found in gardens. (8) Cypress vine or Needle creeper

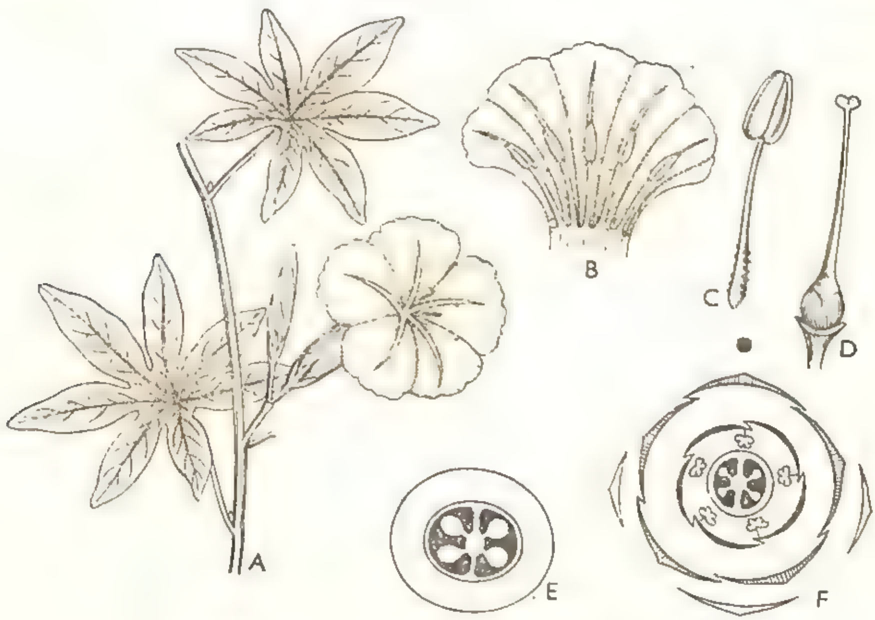


Fig. 642. Convolvulaceae (*Ipomoea pulchella*).
A, Portion of a flowering shoot: B, Corolla split open; C, Stamen; D, Pistil; E, T.s. of fruit; F, Floral diagram.

(*Quamoclit pinnata* Boj. =*I. quamoclit* L.), a small annual garden twiner with pinnatisect leaves and crimson flowers. (9) Christmas vine (*Porana paniculata* Roxb.), a common garden climber. (10) *Argyreia speciosa* Sw. =*A. nervosa* Boj., a garden climber with cordate leaves. (11) *Evolvulus nummularius* L., a common weed which is found on pathways; *E. alsinoides* Wall., also a common weed of grassy places. (12) *Merremia emarginata* Hallier f., a prostrate creeping herb rooting at the nodes. (13) Bind weed (*Convolvulus arvensis* L.), a common weed found on sands. (14) Goat's foot (*Ipomoea biloba*

Forsk.), the leaves of which resemble the hoofs of a goat, is a sand-binder found on sea-shores; *I. pes-caprae* Sweet, another sand-binding herb. (15) Dodder (*Cuscuta reflexa* Roxb.), a common twining golden yellow leafless thread-like parasite. (16) *Rivea hypocrateriformis* Choisy, a large climber. (17) *Stictocardia tiliaefolia* Hallier f., a large climber found in salt-lakes and Sundribans. (18) *Cressa cretica* L., found in dried-up muddy places near saltlakes. (19) *Jacquimontana cerulea* Choisy, a garden plant. (20) *Lettsomia strigosa* Roxb.

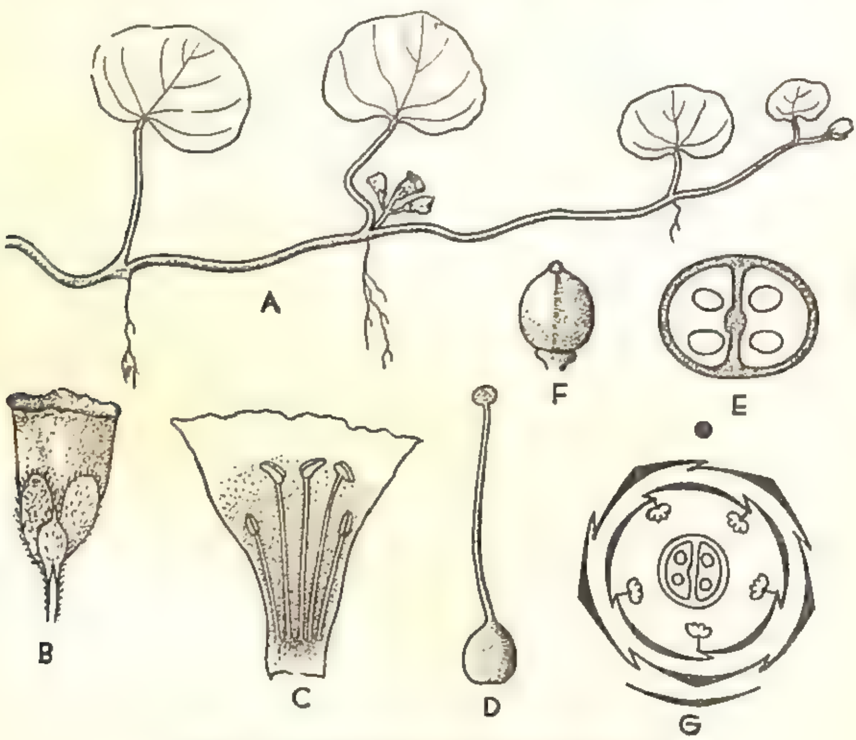


Fig. 643. Convolvulaceae (*Merremia emarginata*).
A, Portion of a flowering shoot; B, Flower; C, Corolla split open; D, Pistil; E, T.s. of ovary; F, Fruit; G, Floral diagram.

Argyreia capitata Choisy, a strong climber commonly found in hedges and village-shrubberries. (21) *Hewittia bicolor* Wight, a perennial twining herb, bearing pale yellow flower with dark purple eye, very common.

Affinity

Convolvulaceae establishes a close relationship with Solanaceae in the presence of false septum, persistent calyx, structure of corolla

and intraxylary phloem so the families Convolvulaceae, Solanaceae, Nolanaceae and Scrophulariaceae have been grouped into a single Order Solanales, next to Loganiales. The family is also allied to Polemoniaceae and Boraginaceae, but readily distinguished by the watery latex, twisted corolla, terminal style, structure of ovary and nature of the embryo.

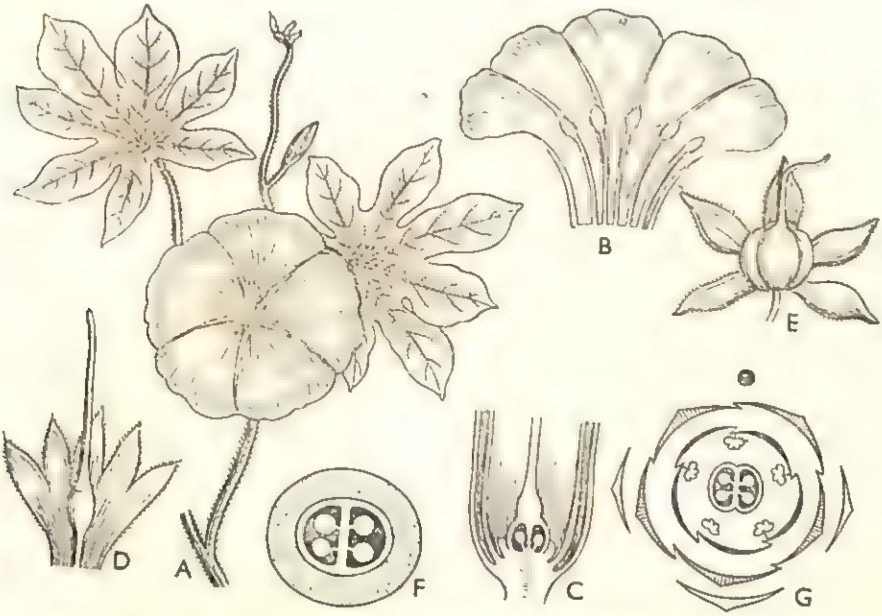


Fig. 644. Convolvulaceae (*Ipomoea pes-tigridis*).
A, Portion of a flowering shoot; B, Corolla split open; C, V.s. of lower portion of a flower; D, Calyx split open showing pistil; E, Fruit; F, T.s. of ovary; G, Floral diagram.

Economic importance

Economically this family is less important. *Ipomoea paniculata* is used medicinally. The tuberous root of *I. batatas* are edible. Some plants are used as ornamentals, such as, cypress vine (*Quamoclit pinnata*), moon flower (*Calonyction aculeatum*), morning glory (*Ipomoea purpurea*), Christmas vine (*Porana paniculata*), etc.

BORAGINACEAE

General characters

Plants—chiefly annual or perennial herbs, sometimes shrubs or trees (e.g., *Cordia*, *Ehretia*). Leaves—usually alternate, simple,

entire, often hispid, exstipulate. Inflorescence—simple or double *scorpioid cymes* which are spirally coiled in the young condition. Flowers—*regular* (but zygomorphic in *Lycopsis*), bisexual, hypogynous, with a disc beneath the ovary. Sepals—5, free or united below into a longer or shorter tube, generally bell-shaped, imbricate. Petals—(5), rotate or funnel-shaped or salver-shaped, usually imbricate; throat often closed by scale-like outgrowths. Stamens—5, epipetalous, *equal or less commonly unequal*. Carpels—(2); ovary 2-celled with 2 ovules in each cell, but afterwards 4-celled with 1 ovule in each cell; style terminal or gynobasic; stigma simple. Fruit—usually of 4 nutlets, sometimes drupe (e.g., *Cordia*, *Ehretia*). Seeds—albuminous or exalbuminous with curved embryo, radicle turning upwards.

Number and distribution

This family consists of about 100 genera and 2,000 species which are chiefly found in the temperate regions.

Key to Genera

A. Style terminal

(*a*) Style 2-partite on ovary; fruit a drupe with four 1-seeded stone; calyx enlarging in fruit; usually trees or shrubs .. .. *Cordia.*

(*b*) Style 2-fid at the apex; pyrenes 2 or 4 or rarely 1-seeded; trees or shrubs .. .. .. *Ehretia.*

(*c*) Style more or less separate; pyrenes 4, 1-seeded; prostrate herbs .. .. *Coldenia.*

(*d*) Style filiform; stamens 5, anthers lanceolate conniving in a cone; calyx enlarged in fruit; ovary deeply 4-lobed and 4-celled; fruit pyramidal; erect herbs .. *Trichodesema.*

(*e*) Style on entire ovary, dilated at the apex or above the base; plants herbaceous .. .. *Heliotropium.*

B. Style gynobasic

Fls. all sessile or only the lower ones pedicelled; stamens included; nutlets obovoid, glochidiate, depressed .. *Cynoglossum.*

Range of floral structures

The flowers are radially symmetrical but a deviation from the normal symmetry takes place also, as in *Echium* and some other genera. In *Lycopsis*, the corolla tube becomes bent as a result of which it assumes zygomorphy.

The aestivation of the sepals is usually imbricate but sometimes valvate type of aestivation also occurs. The sepals may be united or free at the base, as in *Lythospermum*, or connate in *Myosotis*.

Corolla shows also variation in their form. Rotate corolla is seen in the genus *Symphytum*, salver-shaped corolla occurs in *Anchusa*, but funnel-shaped in *Cynoglossum*. The throat of the corolla tube is either naked or closed, as in *Lythospermum*, and there are five pencils of hairs found in the funnel-shaped corolla, as in *Pulmonaria*.

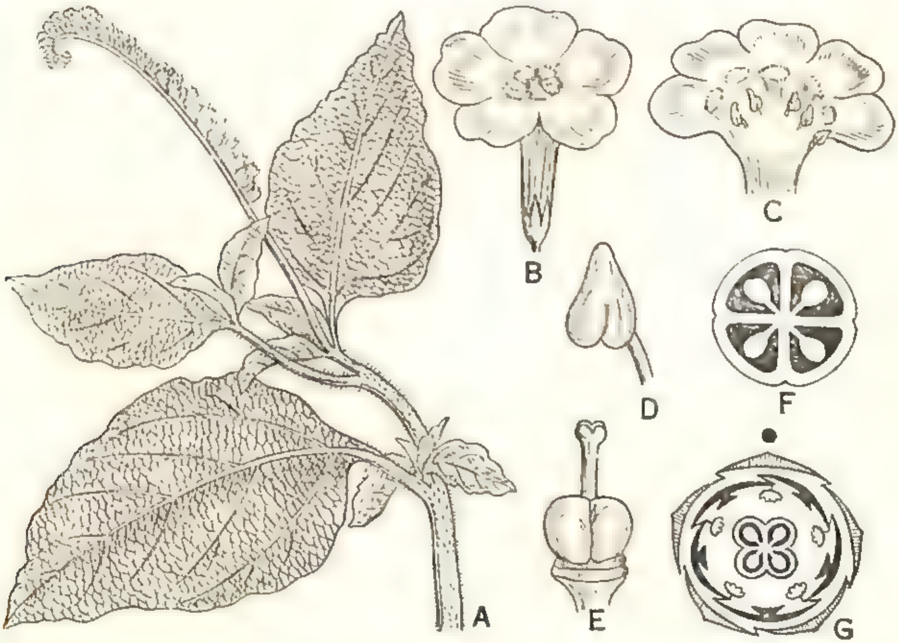


Fig. 645. Boraginaceae (*Heliotropium indicum*).
A, Portion of a flowering shoot; B, Flower; C, The same split open; D, Stamen; E, Pistil; F, Fruit; G, Floral diagram.

The ovary is situated on a nectar-secreting disc which looks like a ring. The two carpels are median. They become divided by a sort of medium constriction or divided into four prominent one-ovuled portions, the style springing from the central portion rather the focus of the group. In the subfamilies **Cordioideae** and **Erhetioideae,** the ovary is seen to maintain its original structure and bears the style on its apex. One ovule is found to be attached at the inner angle of each ovary-segment; it is usually anatropous

with an upwardly directed micropyle. In the subfamily **Heliotropioideae,** the ovule becomes descending with a downwardly projected micropyle. The style usually becomes ended in a simple stigma, such as, *Symphytum*, *Myosotis;* the stigma becomes bilobed, as in *Anchusa*, *Pulmonaria*, whereas the style becomes bipartite in *Echium*.

The styles are generally terminal in the genera, such as, *Cordia*, *Ehretia*, *Heliotropium;* but gynobasic styles are found in *Borago*, *Cynoglossum* and others.

Common plants

(1) Heliotrope (*Heliotropium indicum* L.), a common weed found everywhere with flowers in scorpioid cymes. (2) *Heliotropium ovalifolium* Forsk., a weed found in rice fields and beds of dried tanks. (3) *Heliotropium curassavicum* is often planted in gardens. (4) *Cordia myxa* L. = *C. dichotoma* Forst. f., a small deciduous tree chiefly found in the forests. (5) *Cordia sebestena* L., often planted in gardens for its showy orange-red flowers. (6) *Trichodesma indicum* R. Br., an annual herb found growing in fields and waste places. (7) Forget-me-not (*Myosotis paulutris* Benth.), common in Darjeeling. (8) *Ehretia acuminata* R. Br. = *E. serrata* Roxb., a tree 40 ft. high. (9) *E. laevis* Roxb. = *E. pubescens* Benth., a small tree, can be found in the Indian Botanic Garden. (10) *Cynoglossum lanceolatum* Forsk., an erect annual herb widely distributed. (11) *Coldenia procumbens* L., a flatly prostrate annual herb.

Affinity

This family is closely allied to Polemoniaceae and Hydrophyllaceae. There has been made a separate Order Boraginales under which the above three families have been placed. The Boraginales establish a link between Solanales and Verbenales. Boraginaceae also bears a close relationship with Solanaceae. It has resemblance with that of Labiatae in the structure of fruits and in the presence of nectar-secreting disc which is hypogynous, but it is readily distinguished by alternate leaves, scorpioid inflorescence, regular corolla with scales at the throat and character of fruit. It also bears affinity with Verbenaceae in the general organization of flowers.

Economic importance

This family is of little economic importance. Some plants are used as ornamentals, such as, *Cordia*, *Ehretia*, *Myosotis*, etc.

VERBENACEAE

General characters

Plants—herbs, shrubs or trees, often with square stems. Leaves—usually opposite or whorled, simple, sometimes pinnately or palmately compound (e.g., *Vitex*), exstipulate. Inflorescence—racemose or cymose, often with well-developed bracts. Flowers—usually irregular, bisexual, hypogynous. Sepals—(5), tubular or

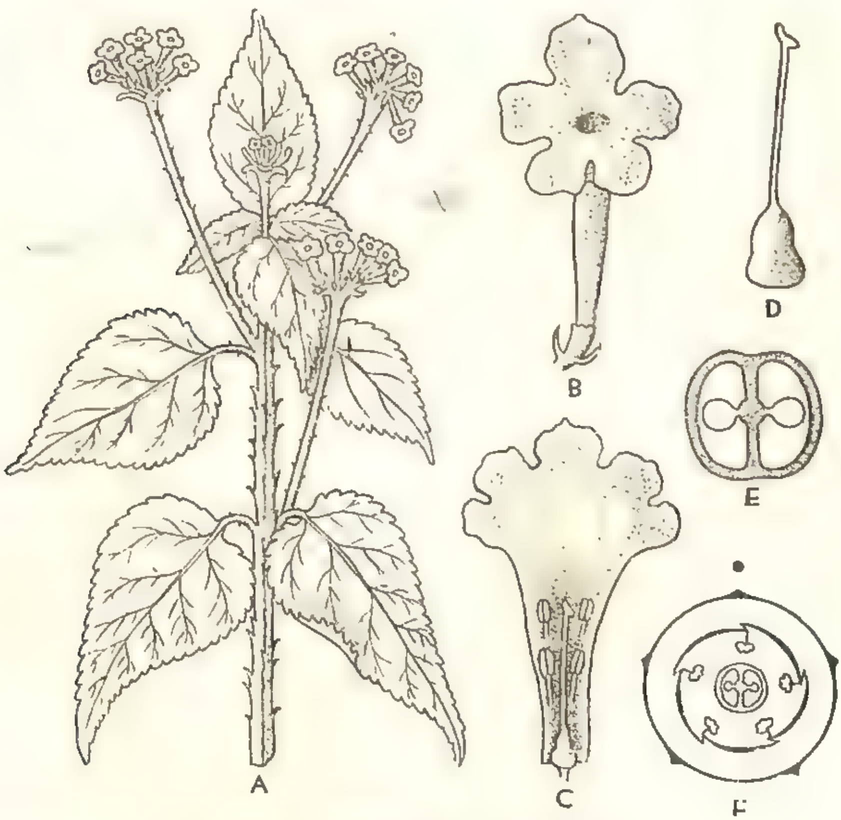


Fig. 646. Verbenaceae (*Lantana camara*).
A, Portion of a flowering shoot; B, Flower; C, Corolla tube split open; D, Pistil; E, T.s. of ovary; F, Floral diagram.

bell-shaped or bilabiate, persistent. Petals—(5), *tubular, often oblique* with a spreading limb, imbricate. Stamens—4, didynamous or 2, rarely 5 (e.g., *Tectona*), epipetalous. Carpels—(2), (but (4) in *Duranta*); ovary superior, more or less lobed, often 2-4-*celled* with 2 *or* 1 *ovule in each cell;* style terminal. Fruit—usually *drupaceous* or of 4

nutlets (e.g., *Verbena*), rarely capsule (e.g., *Avicennia*). Seed exalbuminous. Embryo—straight, with radicle turned downwards.

Number and distribution

This family consists of 80 genera and about 800 species belonging to the southern tropical and temperate regions.

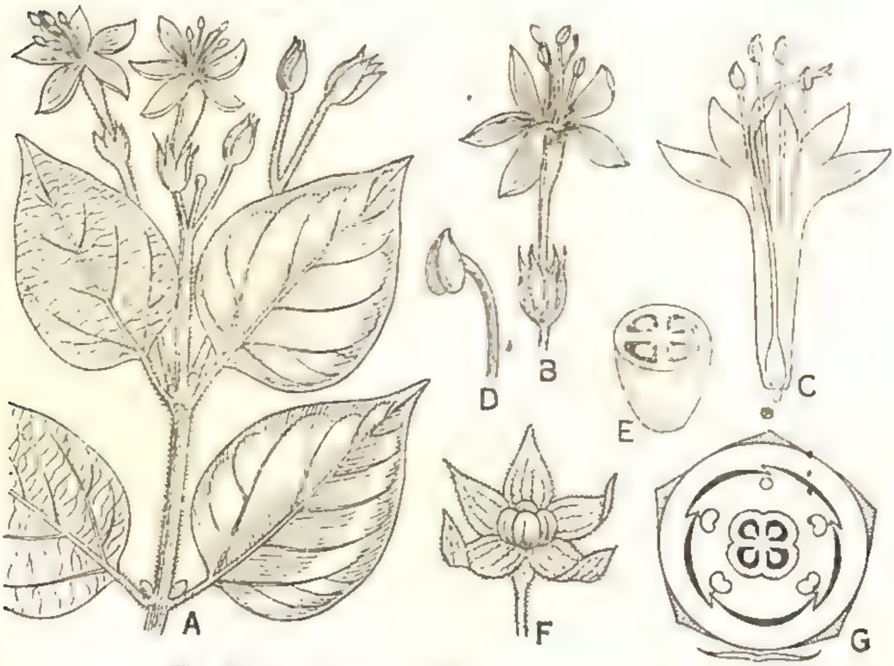


Fig. 647. Verbenaceae (*Clerodendron infortunatum*).
A, Portion of a flowering shoot; B, Flower; C, The same split open; D, Stamen; E. T.s. of fruit; F. Fruit with persistent calyx; G, Floral diagram.

KEY TO GENERA

A. Inflorescence racemose, centripetal, spicate
Small flowers, sessile, clustered in heads, corolla 4 or 5 (2-lobed)

(i) Fruit drupe; 2 pyrenes; small calyx; shrubs .. *Lantana.*
(ii) Fruit capsule, 2 pyrenes; small calyx .. *Lippia.*
(iii) Fruit separating into two 1-seeded pyrenes .. *Stachytarpheta.*
(iv) Fruit pyrenes 4 or 1; calyx tubular, non-accrescent; herb .. .. *Verbena.*
(v) Fruit fleshy, 2-seeded pyrenes .. .. *Duranta.*

B. Inflorescence cymose, centrifugal or panicled

Small flowers; corolla regular; stamens isomerous: leaves entire

(*vi*) Fls. 4-6-merous; anthers exserted; fruit a drupe with 1, 4-celled pyrenes, enclosed in fleshy calyx .. .. *Tectona.*

(*vii*) Fls. 4-merous; anthers exserted; fruit a round drupe with 4 pyrenes .. .. .. *Callicarpa.*

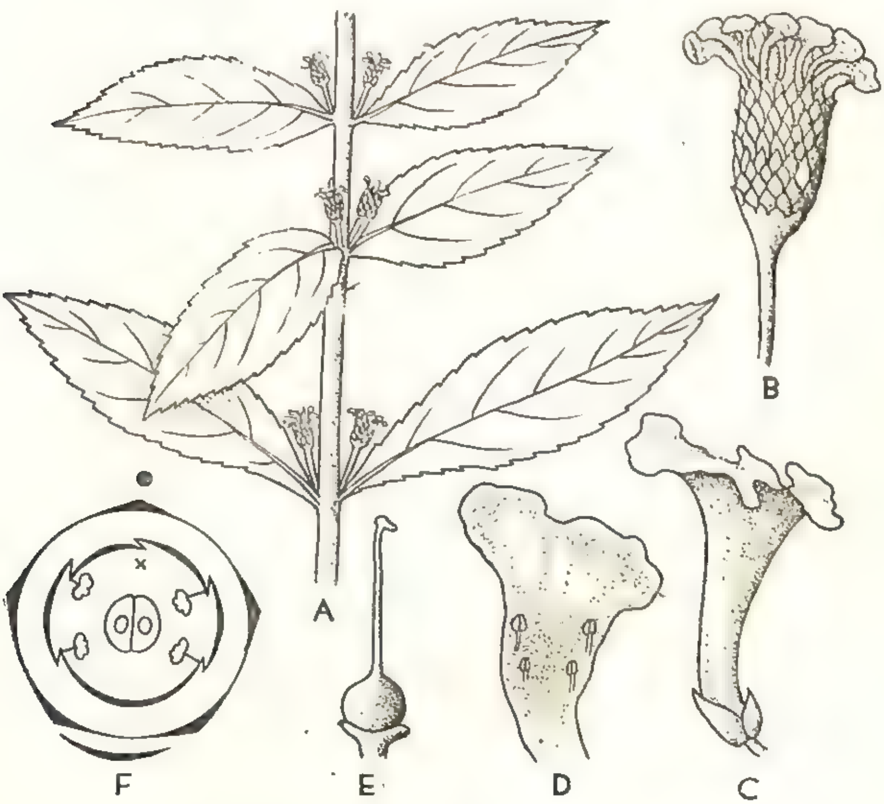


Fig 648. Verbenaceae (*Lippia geminata*).
A, Portion of a flowering shoot; B, Inflorescence; C, Flower; D, Corolla tube split open; E, Pistil; F, Floral diagram.

Small flowers; corolla 2-lipped; stamens didynamous

(*a*) Succulent drupe with single pyrene

(*viii*) Leaves entire or toothed .. .. *Premna.*

(*ix*) Leaves entire; fls. large, 1 inch long .. *Gmelina.*

(*x*) Leaves digitate, 3-5-foliate .. .. *Vitex.*

(*b*) Fruit drupe with 4 pyrenes; leaves simple

(*xi*) Calyx bell-shaped; corolla tube long, slender: stamens equal or didynamous; drupe round .. *Clerodendron*.

(*xii*) Calyx large, petaloid (red), rotate; usually a climbing or straggling shrub .. .. *Holmskioldia*.

C. Inflorescence capitate cyme

(*xiii*) Bracts (involucral) 6 or 3-4; large: fruit usually dry; corolla 2-lipped; large climber .. *Congea*.

(*xiv*) Calyx 5-partite, concave, imbricate; fruit fleshy capsule, 1-seeded; fls. small; shrubs with leathery leaves .. .. *Avicennia*.

Range of floral structures

The flowers are usually pentamerous. The genus, *Physopsis* represents tetramerous flowers which exhibit a reduction in calyx. The tendency to zygomorphy is less marked in calyx than in the corolla, where an upper lip is formed by the union of the two upper lobes, as in *Lantana*, *Lippia* and others. The sepals show valvate aestivation and the petals, imbricate aestivation.

The 5-merous stamen is very rare, seems to be found in *Tectona* and *Geunsia*. The fifth stamen is generally represented by a staminode but it is usually obsolete. Stamens sometimes become diandrous which are formed by the reduction of staminodes of the two posterior or more rarely the two anterior stamens. The four stamens in some genera become fertile and equal.

The carpels are two in number and they are median, sometimes four carpels occur, as in *Duranta*, or five, as in *Geunsia*. In *Lantana*, *Lippia* and others the posterior carpel is abortive.

The ovary sometimes becomes rounded, but usually more or less lobed basing on the number of chambers. In *Lantana* the ovary is two-lobed but it is four-lobed in *Clerodendron* and *Verbena*.

Common plants

(1) Teak (*Tectona grandis* L.), an useful timber tree. (2) Chaste-tree (*Vitex negundo* L.), a common shrub with trifoliate or quadrifoliate leaves. (3) *Clerodendron infortunatum* Gaertn. = *C. viscosum* Vent. and *C. inerme* Gaertn., common herbs chiefly found on waste lands; *C. siphonanthus* R. Br., a tall shrub about 6 ft. high with hollow stems. (4) *Petraea volubilis* Jacq., a climber, very common in gardens. (5) *Duranta plumieri* Jacq., a common hedge-plant with blue flowers and succulent yellow berries. (6) *Lantana indica* Roxb. and *L. camara* L.,

weeds chiefly found along roadsides. (7) *Lippia nodiflora* Rich. = *Phyla nodiflora* Green, a herb commonly found in moist places, and *L. geminata* H. B. & Kunth., a shrub 3-8 ft. high. (8) Verbain (*Verbena officinalis* L.), a small weed of waste places. (9) *Holmskioldia sanguinea* Retz., a shrub commonly planted in gardens for the sake of its flowers. (10) The white Mangrove (*Avicennia officinalis* L.), a common tree with long pneumatophores found in the saltlakes near Calcutta and Sundribans, the seeds of which are viviparous.

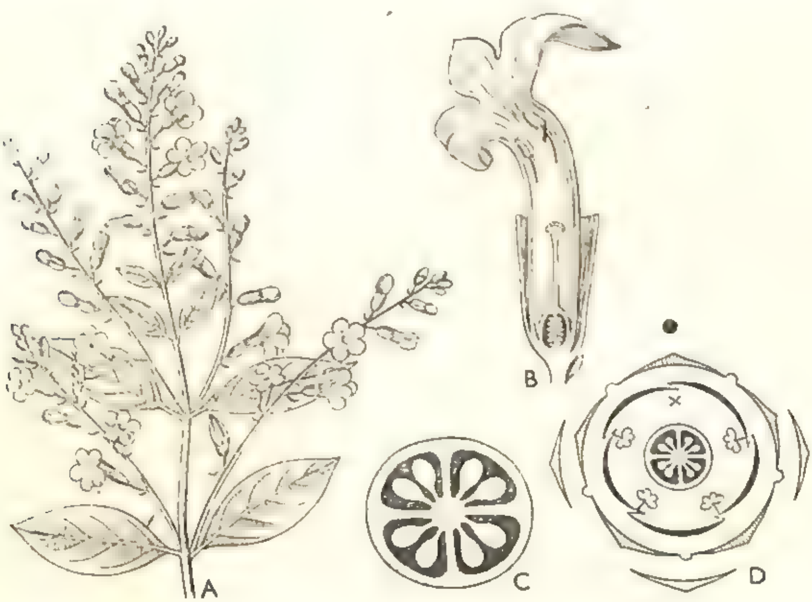


Fig. 649. Verbenaceae (*Duranta plumieri*).
A, Portion of a flowering shoot; B, Flower cut lengthwise;
C, T.s. of ovary; D, Floral diagram.

(11) *Gmelina arborea* Roxb., a tree 60 ft. high. (12) *Gmelina hystrix* Schult. = *G. philippensis* Cham., a garden plant. (13) *Premna integrifolia* L., a shrub or small tree, chiefly found in the Sundribans. (14) *Callicarpa macrophylla* Vahl., common on roadsides and village shrubberies. (15) *Callicarpa arborea* Roxb., a tree about 40 ft. high. (16) *Congea tomentosa* Roxb., a large climber. (17) Aron's rod (*Stachytarpheta indica* Vahl.), a herb 1-2 feet high.

Affinity

This family is closely allied to Acanthaceae and Labiatae but

readily distinguished from the former by 2-4-celled ovary with 2 or 1 ovule in each cell and character of fruit, and from the latter by the form of the inflorescence and terminal style. It also establishes a link with Boraginaceae.

Economic importance

This family is perhaps most important economically. The leaves of *Vitex* are reputed as febrifuge. *Tectona grandis* produces a useful timber. Some plants are used as ornamentals, such as, *Clerodendron, Duranta, Holmskioldia, Lantana, Verbena, Vitex, Callicarpa, Petraea*, etc.

LABIATAE

General characters

Plants—usually annual or perennial herbs or shrubs, seldom trees (e.g., *Leucosceptrum*) with *square stems* and aroma. Leaves—opposite and decussate, simple, exstipulate, more or less hairy. Inflorescence—*verticillaster* or fascicles of axillary cymes or dense spike. Flowers—usually irregular, bisexual, hypogynous. Sepals—(5), bell-shaped or tubular, sometimes bilabiate, persistent. Petals—(5), *bilabiate*, imbricate. Stamens—usually 4, didynamous, or sometimes 2 (e.g., *Salvia, Meriandra*), epipetalous. Carpels—(2); ovary superior, *4-celled* and *deeply 4-lobed* with a single anatropous erect basal ovule in each cell; *style* usually *gynobasic*. Fruit—*carcerule*, consisting of 4 one-seeded nutlets. Seed—exalbuminous. Embryo—with flat plano-convex cotyledon parallel to the fruit-axis.

Number and distribution

This family consists of about 200 genera and 3,200 species which are chiefly found in the warmer and temperate regions.

Key to Genera

A. Stamens 4 perfect, rarely 2; anther-cells 2, confluent; ovary 4-partite; dry nutlets with basal scars

(*a*) Lower corolla-lip flat

(*i*) Calyx segments deflexed in fruit; upper lip large, decurrent; stigma bifid; racemes bearing whorls of 6-10 fls.; herbs or shrubs .. .. *Ocimum.*

(*b*) Lower corolla-lip concave, boat-shaped

(*ii*) Calyx-segments 5, equal or rarely toothed; filaments free .. .. .. *Plectranthus.*

(*iii*) Calyx 5, always 2-lipped; stamens 4; filaments connate below; herbs or shrubs with fleshy stem and leaves .. .. *Coleus.*

(*c*) Corolla obscurely 2-lipped with 2 upper lobes flat, similar and subequal to two laterals, all about as long as the abruptly deflexed, saccate lower lip; calyx teeth subequal .. .. *Hyptis.*

Fig. 650. Labiatae (*Ocimum sanctum*).
A, Portion of a flowering shoot; B, Flower; C, V.s. of the same; D, Gynobasic style; E, Fruit; F, Floral diagram.

B. Stamens 4, upper pair long; anthers 1- or 2-celled; corolla flat

(*i*) Calyx 5-toothed, ovoid; core subequally 4-lobed; stamens exserted; filaments bearded; small plants with whorled leaves and densely spicate fls. .. *Dysophylla.*

(*ii*) Calyx 5-toothed; lower corolla-lobe subpatent; stamens exserted; whorls in glomerate or panicular spike; filaments bearded or naked .. *Pogostemon.*

(*iii*) Calyx 5-partite, plumose segments; stamens included; fruit-nutlets ovoid; hairy plants, usually hoary shrubs, with opposite crenulate leaves .. *Colebrookia.*

(*iv*) Calyx 5-toothed, often enlarged and inflated in fruits; corolla tubular, incurved or straight; stamens diverging with divaricate anther-cells; plants herbs or undershrubs with opposite leaves .. .. *Elsholtzia.*

C. Stamens 4, perfect, lower pair longest; calyx 5-10-nerved; upper lip of corolla hooded, villous; anther-cells 2, diverging

(*i*) Upper corolla-lip short, flat, pubescent; anther-cells of upper pair dimidiate and those of lower ones parallel; tall coarse herbs .. *Anisomeles.*

(*ii*) Upper corolla-lip hooded, purple, villous; calyx 5, spinous; anther-cells parallel; fls. in dense axillary whorls; plants erect herbs with square stem and pinnately lobed leaves .. .. *Leonurus.*

(*iii*) Upper corolla-lip hooded; lower lip large, white; calyx 8-10-toothed; fls. in axillary or terminal whorls; plants usually hoary herbs .. *Leucas.*

(*iv*) Upper corolla-lip large, hooded; lower lip very small; calyx 8-10-toothed; bracteoles many; fls. scarlet or yellow, borne in axillary whorls .. *Leonotis.*

D. Stamens 2, parallel; anther-cells linear

(*i*) Anther-cells equally, distantly pendulous from a long connective; calyx ovoid, upper lip concave, lower 2-fid; style bilamellate; hoary shrubs .. *Meriandra.*

(*ii*) Anther-cells unequal or single on prolonged connective; fls. large showy with 2-lipped calyx; upper lip of corolla arched; herbs or shrubs .. *Salvia.*

(*iii*) Floral whorls many-fid; calyx 10-nerved; anther-cells parallel; fls. sometimes borne in terminal spike; corolla 4-lobed, subequal; a strongly scented perennial herb with creeping rootstock *Mentha.*

Range of floral structures

Labiatae includes a group of plants which are found to possess variable characters in their floral parts.

The calyx may be tubular, bell-shaped or spherical, straight or bent. The variation in the form of teeth or lobes is noticeable. Calyx is regularly 5-toothed; it may be 2-lipped, as in *Plectranthus*, *Thymus* and *Salvia*, or a fleshy calyx, as found to occur in *Hoslundia*.

The corolla also shows a great variation in their structure. It

can be differentiated into two portions—the tube and limb. The tube is generally found to be straight or variously bent. The limb is equally 5-toothed. The general arrangement of corolla is bilabiate, as in *Thymus*; in *Mentha*, the corolla is tetra- or penta-merous. 4/1 arrangement (4 petals forming the upper lip and a single petal, the lower lip) is found to occur in *Ocimum*, *Hyptis*. 0/5 arrangement exists in the genus *Teucrium*.

The development of 5th posterior stamen is very rare. It is sometimes found as a staminode, but usually it is totally suppressed.

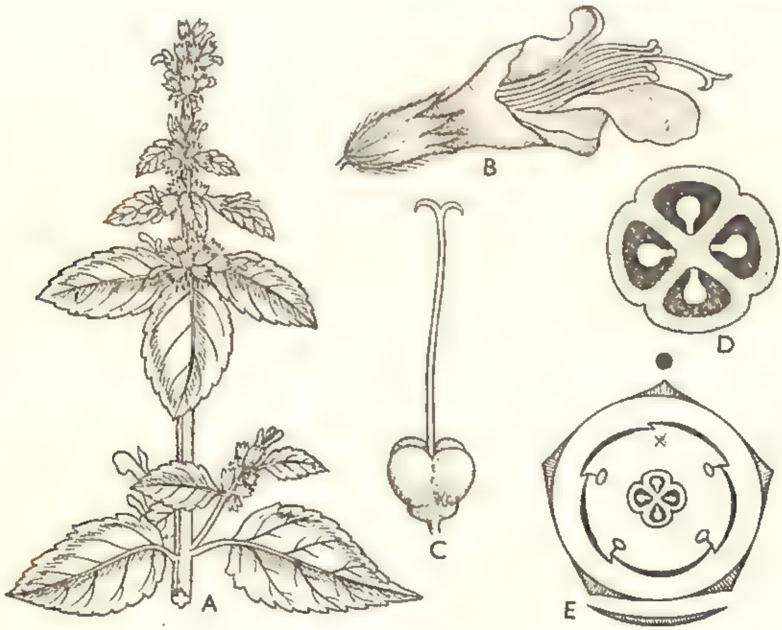


Fig. 651. Labiatae (*Anisomeles ovata*).
A, Portion of a flowering shoot; B. Flower; C, Pistil; D, T.s. of ovary; E, Floral diagram.

The two upper stamens are reduced to staminodes or they are found to be completely suppressed, as in *Lycopus*, *Salvia*. In *Coleus* the stamens are found to unite into a bundle; in *Nepeta*, the anterior pair is longer. A variation is also noticeable in the connectives of anthers. The presence of number of connectives is not broad and generally with two parallel theca, occurs in Ocimoideae; the wide transverse connective with two fertile anther-lobes is found in the genus *Meriandra*. The long connectives with one sterile anther-lobe are found in the species of *Salvia*, *Hemigenia*.

The style is generally gynobasic, except in *Teucrium* and *Ajuga*.

Common plants

(1) Basil (*Ocimum sanctum* L.). (2) *Ocimum basilicum* L., commonly found on roadsides; *O. canum* Sims., a herb 1-2 ft. high. (3) *Ocimum gratissimum* L., a shrub. (4) Sage (*Salvia plebeja* R. Br.), an annual weed and *S. coccinea* L., a commonly cultivated garden plant with brightly coloured sepals and petals. (5) Motherwort (*Leonurus sibiricus* L.), a common weed on roadsides, with pink flowers and

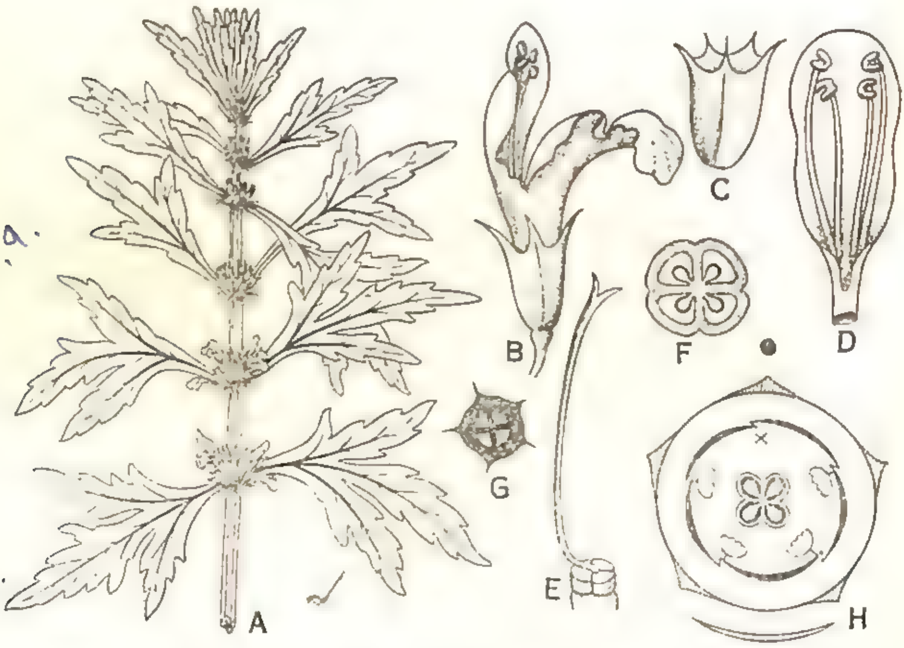


Fig. 652. Labiatae (*Leonurus sibiricus*).
A, Portion of a flowering shoot; B, Flower; C, Calyx; D, V.s. of corolla; E, Pistil; F, T.s. of ovary; G, Fruit; H, Floral diagram.

heteromorphic foliage. (6) *Leucas aspera* Spreng. = *L. mollisima* Wall. and *L. linifolia* Spreng. = *L. lavendulaefolia* Nees., common annual herbs with white flowers; *L. procumbens* Desf., a slender procumbent herb. (7) Mint (*Mentha viridis* L.), cultivated in gardens for leaves which are used as condiment. (8) Pippermint (*Mentha piperita* L.), the leaves of which on distillation yield menthol. (9) *Lavandula vera*, produces oil of lavender. (10) *Anisomeles ovata* Br. = *L. indica* O. Kuntze., a weed of waste places. (11) Thyme (*Thymus serpyllum* L.),

thymol-producing plant. (12) *Pogostemon heyneanus* Benth. (*Patchouli*), used in perfumery. (13) Rosemary (*Rosmarinus officinalis*), a medicinal plant. (14) Several species of *Coleus* (e.g., *C. aromaticus* Benth.) are ornamental garden plants. (15) *Leucosceptrum canum* Sm., a

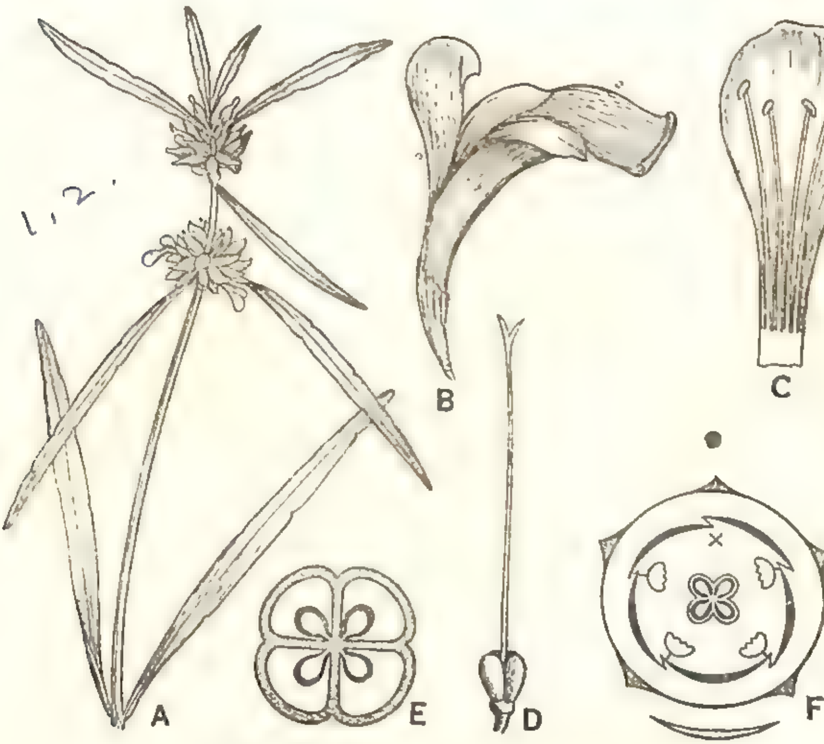


Fig. 653. Labiatae (*Leucus linifolia*).
A, Portion of a flowering shoot; B, Flower; C, V.s. of the same; D, Pistil; E, T.s. of ovary; F, Floral diagram.

native of the Himalayas, is a tall tree, very common in Darjeeling; it has long upright spikes of yellow-white flowers resembling a bottle-brush when old; a quantity of sweet juice exudes from the flowers and this is sucked up by the herdsmen. (16) *Dysophylla verticillata* Benth., a variable weed of rice fields and swamps, much-branched or simple. (17) Lion's ear (*Leonotis nepetifolia* R. Br.), an annual herb, 4-6 ft. high. (18) *Meriandra benghalensis* Benth., a large straggling shrub found in the gardens. (19) *Plectranthus ternifolius* Don., a bushy herb 3-5 ft. high commonly found in North Bengal. (20) *Colebrookia oppositifolia* Sm., a shrub 5-10 ft. high, can be found in the Indian Botanic Garden. (21) *Elsholtzia polystachya*

Benth., occasionally found. (22) *Hyptis suaveolens* Poit., a very common rigid annual, 2-4 feet high. (23) *Pogostemon plectranthoides* Desf., a large bush, can be found in all the provinces.

Affinity

This family, especially the subfamilies Ajugoideae and Plectrantheroideae, bears an affinity with Verbenaceae in the character of terminal style. It is also allied to Boraginaceae but distinguished from the latter by the character of the ovule. The family is closely allied to Acanthaceae but readily distinguished by the verticillaster inflorescence, gynobasic style and character of ovary and fruit. It is highly advanced among gamopetalous families as regards elaborate floral structure and entomophilous adaptation for pollination.

Economic importance

This family has got some economic importance. Some plants are used in medicine, such as, *Ocimum*, *Rosmarinus*, *Thymus*, *Mentha*, etc. Lavender oil is obtained from *Lavendula vera*. *Pogostemon heyneanus* is used in perfumery. Some are ornamentals, such as, *Coleus*, *Colebrookia*, *Salvia*, *Leucosceptrum*, *Leonotis*, *Meriandra*, etc.

SOLANACEAE

General characters

Plants—herbs or shrubs, rarely small trees, sometimes climbing. Leaves—alternate, simple, often lobed, exstipulate. Inflorescence—often cymose. Flowers—regular, sometimes zygomorphic, bisexual, hypogynous. Sepals—(5), persistent, often enlarging in the fruit. Petals—(5), usually *rotate or funnel-shaped*, rarely bilabiate, plicate. Stamens—usually 5, alternating with the corolla-lobes, rarely 4, didynamous (e.g., *Brunfelsia*, *Browallia*, *Salpiglossis* and *Schizanthus*), epipetalous; anthers bilocular, dehiscing by apical pores or longitudinally. Carpels—(2), *obliquely placed*; ovary superior, generally 2-celled or falsely 3-5-celled with numerous anatropous ovules on axile placenta; stigma bilobed. Fruit—usually many-seeded *berry*, sometimes capsule (e.g., *Datura*). Seeds—more or less uniform, albuminous. Embryo—usually *curved*, sometimes straight.

Number and distribution

This family consists of about 85 genera and over 2,200 species which are widely distributed throughout tropical and temperate regions.

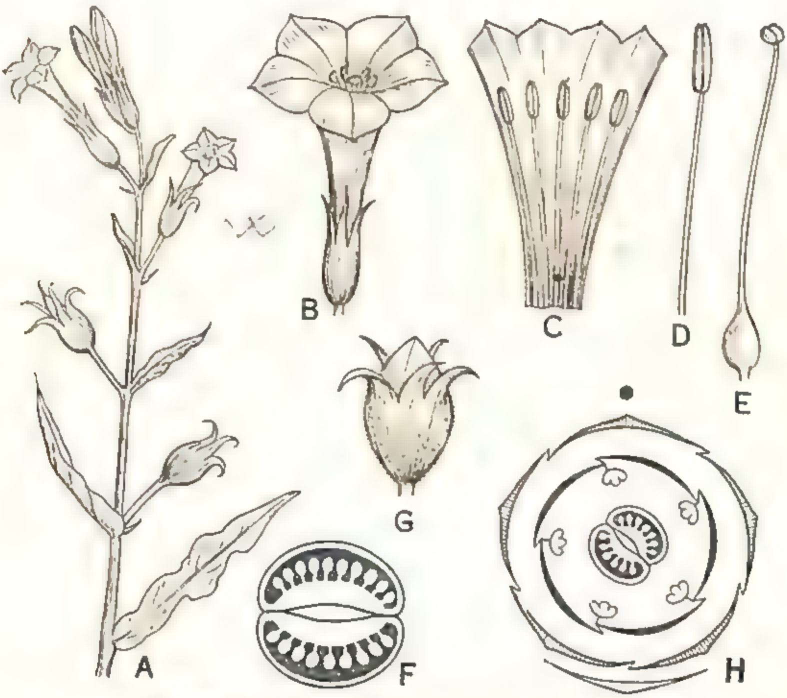


Fig. 654. Solanaceae (*Nicotiana plumbaginifolia*).
A, Portion of a flowering shoot; B, Flower; C, the same cut open; D, Stamen; E. Pistil; F, T.s. of ovary; G, Fruit; H, Floral diagram.

Key to Genera

A. Corolla-limb valvate; fruit usually a berry; seeds more or less discoid, compressed; embryo peripheric

(*a*) Anthers opening through 2 apical pores, connivent in a cone

(*i*) Leaves simple, lobed or pinnatifid .. .. *Solanum.*

(*b*) Anthers dehiscing by longitudinal slit

(*ii*) Dehiscence introrse, leaves pinnate .. *Lycopersicum.*

(*iii*) Calyx small in fruit; anthers equal or shorter than the filament; fls. small, in paired pedicels or simple .. .. *Capsicum.*

(*iv*) Calyx enlarging in fruit, covering the berry, shortly lobed; pedicels solitary .. .. *Physalis.*

(*v*) Calyx enlarging in fruit, overtopping the berry; pedicels clustered .. .. .. *Withania.*

B. Corolla-lobes imbricate; embryo curved

(*vi*) Capsule 4-valved, semi-indehiscent; fls. solitary, axillary; stamens all perfect .. .. *Datura.*

(*vii*) Capsule circumsessile; fls. unilateral, upper racemose .. .. *Hyoscyamus.*

C. Corolla-lobes induplicate-valvate; embryo straight; fruit capsular; fls. panicled .. .. .. *Nicotiana.*

D. Corolla-lobes subplicate-imbricate; embryo straight or slightly curved; fruit membranceous or subcoriaceous capsule; fls. white or blue, solitary axillary, or the uppermost passing into a 1-sided terminal raceme .. *Browallia.*

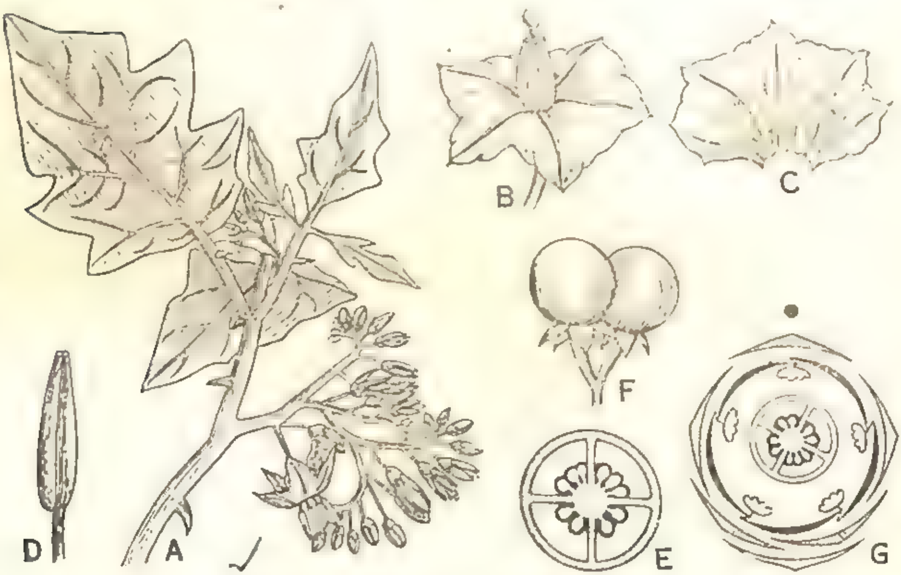


Fig. 655. Solanaceae (*Solanum torvum*).
A, Portion of a flowering shoot; B, Flower; C, Corolla split open; D, Stamen; E, T.s. of ovary; F, Fruit; G, Floral diagram.

Range of floral structures

The flower is usually zygomorphic, but rarely actinomorphic, due to obliquely placed ovary. The corolla is found to be regular as in *Solanum*, which consists of rotate corolla, or the bell-shaped corolla of *Atropa*, or irregular to some extent, as in *Hyoscyamus*.

Zygomorphy is very prominent in *Salpiglossis*. In this genus there are two or four fertile stamens. The corolla may be two-lipped, as in *Schizanthus*. The stamens are usually unequal in their length.

The ovary becomes 1-celled in *Henoonia*, but in *Capsicum* the ovary is also 1-celled in the upper portion. In many genera false partitions are laid down as a result of which 3-5-celled chambers are formed. In *Datura*, 4-celled chamber is seen, but in *Nicandra*, the ovary becomes 3-5-celled.

The number of ovules is generally numerous but occasionally few ovules are found, as in *Cestrum*.

Common plants

(1) Brinjal or Egg plant (*Solanum melongena* L.), a common herb cultivated throughout India. (2) Potato (*Solanum tuberosum* L.). (3) *Solanum xanthocarpum* Schrad. & Wendle, a prickly weed found on roadsides, much used by Indian Kabirajes. (4) *Solanum torvum*

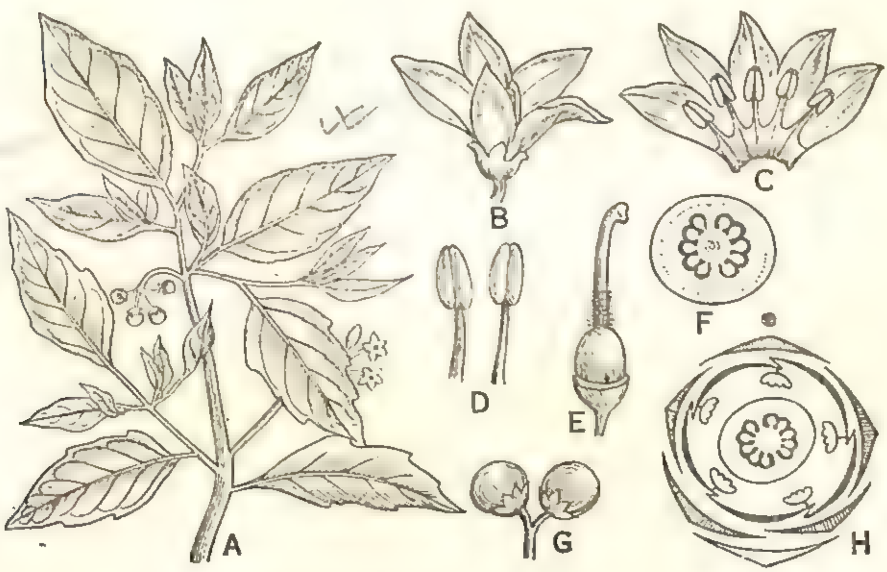


Fig. 656. Solanaceae (*Solanum nigrum*).
A, Portion of a flowering shoot; B, Flower; C, Corolla split open; D, Stamens; E, Pistil; F, T.s. of ovary; G, Fruit; H, Floral diagram.

Swartz., a common shrub. (5) *Solanum ferox* L. (6) *Solanum verbascifolium* L., a large shrub or small tree about 12 ft. in height. (7) Nightshade (*Solanum nigrum* L.), a common weed found everywhere. (8) *Solanum indicum* L., a prickly herb commonly found on roadsides and rubbish heaps. (9) *Solanum trilobatum* L., a prickly climbing plant found in salt lakes near Calcutta. (10) Tomato

(*Lycopersicum esculentum* Mill. = *S. lycopersicum* Mill. , a tall herb, commonly cultivated for globose pulpy fruits. (11) Chili or Red pepper (*Capscium frutescens* L.), cultivated for the scarlet or orange-yellow fruits which are used as condiment. (12 Thorn-apple *Datura fastuosa* L. = *D. metel* L.), a common herb whose seeds are highly poisonous ; Jimson weed (*D. stramonium* L.), another highly poisonous plant from which alkaloid 'daturin' is extracted. (13) Tobacco (*Nicotiana tabacum* L.), a small shrub with sticky glandular hairs. (14) *Nicotiana plumbaginifolia* Viv., a common weed.

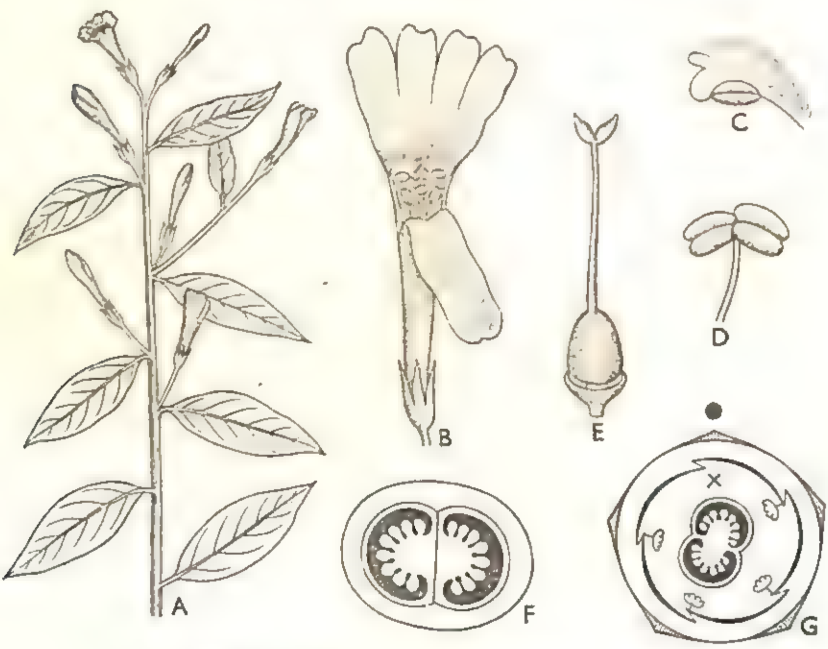


Fig. 657. Solanaceae (*Browallia elata*).
A, An entire plant; B, Flower with corolla torn open;
C; A stamen with hood; D, A shorter stamen; E, Pistil;
F, T.s. of ovary; G, Floral diagram.

(15) *Withania somnifera* Dun., a medicinal plant cultivated in gardens. (16) Cape gooseberry or Ground cherry (*Physalis peruviana* L.), commonly cultivated for the edible fruits which lie concealed within accrescent calyx; *P. minima* L., a common weed in waste places and on the borders of cultivated land. (17) *Cestrum nocturnum* Murray, a common garden plant, the flowers of which emit a sweet odour at night. (18) *Solanum macranthum*, a tree-like plant with pale blue flowers, often cultivated in gardens. (19) *Solanum seaforthianum*, a

climber, very commonly found in Darjeeling with small white flowers. (20) *Brunfelsia*, *Salpiglossis*, *Schizanthus* and *Petunia* are garden plants. (21) Deadly Nightshade (*Atropa belladona* L.). (22) Woody Nightshade or Bitter-sweet (*Solanum dulcamara* L.), and (23) Henbane (*Hyoscyamus niger* L.), are medicinal plants. (24) *Browallia elata* L., an annual garden herb. (25) *Solanum glaucum*, very common at Diamond Harbour. (26) *Cestrum diurnum*, very common on roadsides.

Affinity

This family is allied to Scrophulariaceae but distinguished by the form of the corolla, number of stamens and oblique position of carpels. It differs from Convolvulaceae in having numerous seeds.

According to Engler, this family occupies a position under Order Tubiflorae in the subseries Solanineae. Hutchinson considers this family is related to Convolvulaceae and Boraginaceae. Wettstein accepts the view that Solanaceae is closely associated with Convolvulaceae, that is why he has put the family under Tubiflorae. Rendle is of opinion that the family Solanaceae be placed under Tubiflorae. Hallier considers it as a primitive member of the Tubiflorae and has derived from Linaceae.

Economic importance

This family is of considerable economic importance. Some plants are used as vegetables, such as, *Solanum tuberosum* (potato), *S. melongena* (brinjal), *S. lycopersicum* (tomato), *Capsicum* and others. Some genera are important from medicinal standpoint of view, such as, *Atropa*, *Datura*, *Solanum*, *Hyoscyamus*, etc. Tobacco (*Nicotiana tabacum*) is an important economic plant. Alkaloids, such as, *nicotin* and *daturin* are obtained from *Nicotiana tabacum* and *Datura stramonium* respectively. Some plants are ornamentals, such as, *Petunia*, *Cestrum*, *Datura*, *Browallia*, *Brunfelsia*, *Schizanthus*, etc.

SCROPHULARIACEAE

General characters

Plants—usually herbs or undershrubs, rarely parasitic on roots (e.g., *Lathrea*, *Striga*). Leaves—alternate throughout, or the lower opposite and the upper alternate, or all opposite or whorled,

exstipulate. Inflorescence—racemose (raceme or spike) or cymose (dichasia). Flowers—irregular (sometimes almost regular in *Scoparia*), bisexual, hypogynous, generally *with bracts*. Sepals—(5), more or less deeply 4-5-partite, imbricate or valvate. Petals—usually (5), *personate* or tubular or rarely rotate, imbricate. Stamens—usually 4, didynamous, sometimes 5 (e.g., *Verbascum*) or 2 (e.g., *Veronica*), epipetalous. Carpels—(2), medianly placed; ovary

Fig. 658. Scrophulariaceae (*Antirrhinum majus*).
A, Portion of a flowering shoot; B, V.s. of a flower; C, T.s. of ovary; D, V.s. of ovary; E, Floral diagram.

superior, *usually 2-celled*, rarely 4-celled with *numerous anatropous ovules* on *axile placenta* (but free-central in *Scoparia*); stigma simple or bilobed; style terminal. Fruit—usually a *capsule*, sometimes berry. Seed—albuminous. Embryo—*straight or slightly curved*.

Number and distribution

This family consists of about 210 genera and nearly 3,000 species which are cosmopolitan but chiefly confined to temperate regions.

KEY TO GENERA

A. Corolla tubular, tube saccate to spurred; capsule opening by pores; inflorescence uniform

(*i*) Corolla spurred; anther-cells distinct .. *Linaria.*

(*ii*) Corolla large, saccate below .. .. *Antirrhinum.*

Fig. 659. Scrophulariaceae (*Lindenbergia urticaefolia*).
A, Portion of a flowering shoot; B, Flower; C, Corolla split open; D, Stamen; E, Pistil; F, T.s. of ovary; G, Floral diagram.

B. Corolla personate, with 2 parallel ridges

(*iii*) Calyx campanulate, 5-partite, equal; stamens all perfect; seeds angular; plants usually aquatic with submerged leaves multifid .. .. *Limnophila.*

(*iv*) Calyx campanulate, 5-fid; anther-cells disjoined; capsule loculicidal .. .. .. *Lindenbergia.*

C. Corolla distinctly bilabiate: the anther-cells contiguous but distinct; calyx wide campanulate, 2-fid .. .. *Mazus.*

D. Corolla 5-lobed, without parallel ridges

(*v*) Calyx 5-partite, imbricate; stamens inserted: anther-cells contiguous; corolla white, tinged with purple and yellow; creeping or erect .. *Herpestis.*

(*vi*) Calyx deeply 5-fid; corolla-throat much widened; stamens 2 perfect, 2 staminodes; fls. violet; annual marshy herbs .. .. .. *Dopatrium.*

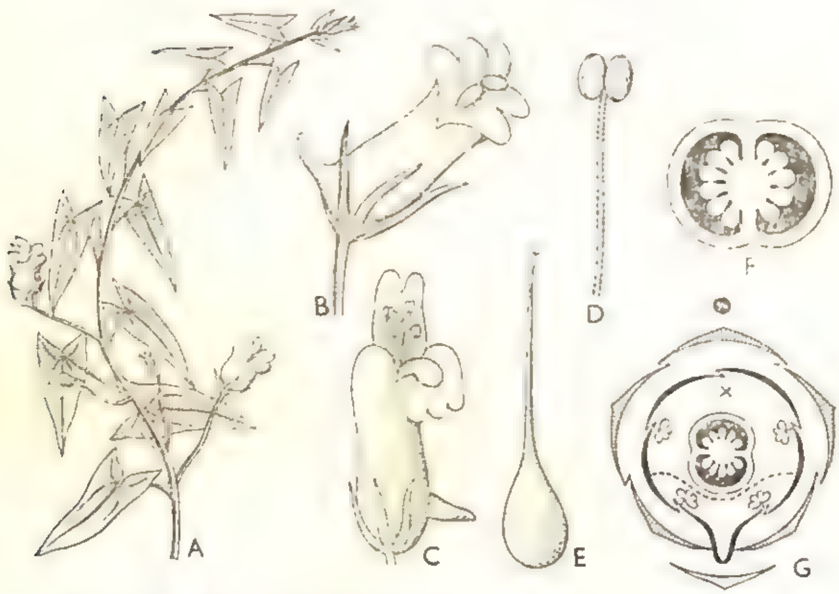


Fig. 660. Scrophulariaceae (*Linaria ramosissima*).
A, Portion of a flowering shoot; B, Flower; C, The same with corolla slightly torn open; D, Stamen; E, Pistil; F, T.s. of ovary; G, Floral diagram.

(*vii*) Calyx 5-toothed; 2 stamens attached to upper lobes, the other 2 stamens to lower lobes, all anthers conniving or cohering in pair .. *Vandellia.*

(*viii*) Calyx tubular, sometimes winged or obliquely 2-lipped; stamens 4, didynamous; fls. showy; fruit a linear capsule .. .. .. *Torenia.*

(*ix*) Calyx segments 5; stamens 2, both perfect; capsule long .. .. .. *Bonnaya.*

E. Corolla-lobes 4, rotate, white, almost regular; stamens 4, perfect with staminal hairs; fruit a small globular capsule with free central placenta .. .. .. *Scoparia.*

F. Corolla-lobes 5, rotate; calyx partite; stamens equal; anthers sagittate or horse-shoe shaped .. .. *Hemiphragma.*

G. Corolla-lobes 5, subovate, with two upper lobes exterior in bud; stamens 4; leaves all alternate .. .. *Celsia.*

H. Corolla tubular, with spreading limbs, abruptly incurved; calyx subcampanulate, 5-toothed; ovary 1-celled, tip mucronate .. .. *Striga.*

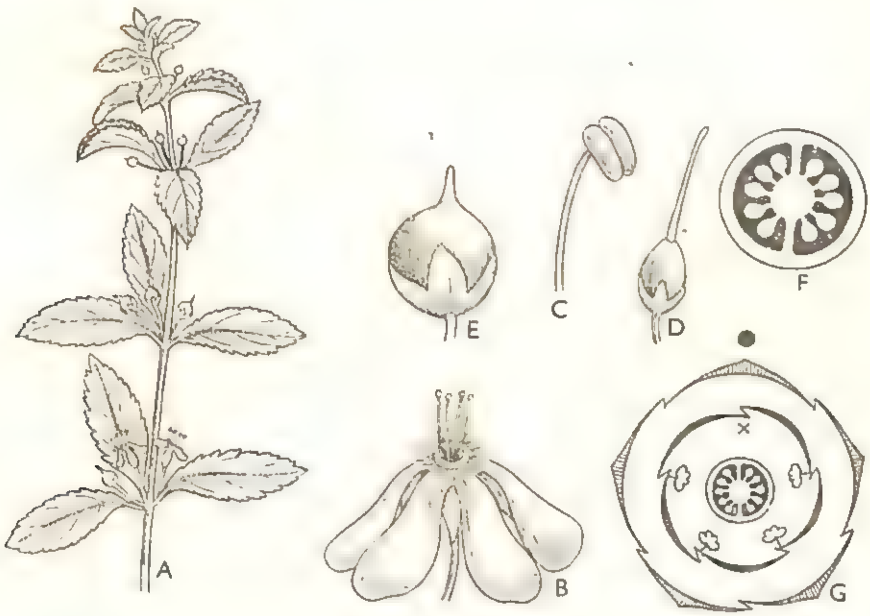


Fig 661 Scrophulariaceae (*Scoparia dulcis*).
A, Portion of a flowering shoot; B, Flower; C, Stamen; D, Pistil; E, Fruit; F, T.s. of ovary; G, Floral diagram.

Range of floral structures

This family shows a considerable variation in their floral structures.

Flowers are usually bracteate and there are also bracteoles. Calyx is generally pentamerous, but reduction in the number of calyx is also manifested in *Euphrasia* and many *Veronicas*, where the general suppression of the posterior sepal occurs. In *Pedicularis*, there are 2-5-toothed calyx and in *Calceolaria*, the two anterior sepals are found to be entirely connate.

The usual zygomorphic corolla shows wide variation in its form based on the length and breadth of the tube. The corolla may be absent in *Veronica* or the corolla may be large and bell-shaped, as in *Digitalis purpurea*. In *Veronica*, the corolla is provided with

spreading limbs. It is small and suberect, as in *Scrophularia*, or the corolla forms a pair of closed lips, as in *Linaria* and *Antirrhinum*. The genus *Linaria* shows a petal which is spurred at the anterior region. In *Diascia*, the lateral anterior petals are spurred. The corolla tube is very short in *Calceolaria*. In this case two lips are found, an upper smaller lip formed by the union of the posterior petals, and a lower larger lip, formed by the three anterior petals. The corolla is seldom regular, as in *Verbascum*, which has five equal segments. The corolla is four-lobed, as in *Veronica*, *Gratiola* and others.

The variation in the number of stamens also occurs in some genera. Five stamens are equal, as in the *Verbascum*, but in its some species there are three posterior longer stamens than the anterior one. In many a genera, the posterior stamen is more or less aborted, but out of four fertile stamens, the anterior pair generally becomes longer than the posterior one, as in *Linaria*, *Digitalis*, etc. Sometimes two stamens only occur in some genera, such as, *Veronica*, *Calceolaria* and others.

The carpels are generally two and equal, but the anterior carpel becomes larger, as in *Antirrhinum*.

Common plants

(1) Snapdragon (*Antirrhinum majus* L.), a common season flower of gardens. (2) *Lindenbergia urticaefolia* Link & Otto. and *L. polyantha* Royle, very common on old walls and edges of roofs bearing small yellow flowers. (3) *Scoparia dulcis* L., a rigid perennial herb, common in waste places with almost regular flowers and corolla-throat densely bearded. (4) Toad-flax (*Linaria ramosissima* Wall.), a prostrate herb with sagittate leaves, commonly found in waste places. (5) *Herpestis monnieria* H. B. & K. = *Bacopa monnieri* Pennel, a small weed reputed for nervine properties. (6) *H. chamaedroides* L., common on pathways. (7) *Celsia coromandeliana* Vahl. = *Verbascum coromandelianus* O. Ktze., a weed. (8) *Bonnaya brachiata* Link & Otto. = *Linderia brachiata* Link & Otto., a weed. (9) *Vandellia crustacea* Benth. = *Linderia crustacea* F. Muell., a common weed. (10) *Limnophila gratioloides* R. Br., a weed of rice fields and damp places; *Limnophila heterophylla* Benth., an aquatic plant with highly dissected submerged leaves, is a typical example of heterophylly. (11) Coral plant (*Russelia juncea* Jacq. = *R. equisetiformis* Schlecht. & Cham.), a closely tufted perennial herb with numerous slender green branches; leaves opposite or

whorled, those on the stem often reduced to scales; very common in garden with crimson-red flowers. (13) Purple Fox-glove (*Digitalis purpurea* L.), a medicinal plant, abundant in Darjeeling. (14) *Torenia calcarata* Griff. and *Verbascum celosioides* Benth. are season flowers. (15) *Dopatrium junceum* Ham., a weed of rice fields and swamps. (16) *Striga densiflora* Benth., a herb 6-8 in. high. (17) *Mazus rugosus* Lour. = *M. japonicas* O. Kunth., a small annual with tufted radical leaves.

Fig. 662. Scrophulariaceae (*Torenia calcarata*).
A, Portion of a flowering shoot; B, Corolla tube split open;
C, Pistil with calyx split open and corolla removed.

Affinity

This family is much allied to Solanaceae, especially with the tribe Salpiglossideae in the floral structure but distinguished by medianly placed ovary, the aestivation of corolla and zygomorphic

corolla. Scrophulariaceae also bears an affinity with other allied families, such as, Orobanchaceae and Gesneraceae, but distinguished from them in their unilocular ovary with parietal placentation. It is distinguished from Bignoniaceae and Pedaliaceae in the absence of endosperm. The family is also allied to Acanthaceae and Labiatae but distinguished by alternate leaves, absence of bracts, forms of corolla, character of ovary and nature of fruit.

Economic importance

The economic value of this family is much limited. Some plants are used in medicine, such as, *Digitalis purpurea*, which yields an alkaloid known as *digitalin*. Among the ornamental plants notable ones are *Antirrhinum* (snapdragon), *Calceolaria* (slipper flower or lady's bag), *Veronica*, *Russelia* (coral plant), *Torenia*, *Digitalis* (foxglove), etc.

Comparison of Convolvulaceae, Solanaceae and Scrophulariaceae

Convolvulaceae	*Solanaceae*	*Scrophulariaceae*
1. Plants—annual or perennial herbs.	1. herbs, shrubs or small trees.	1. herbs or undershrubs.
2. Leaves—simple (entire or palmatisect), alternate, exstipulate.	2. usually simple (entire or lobed), alternate, exstipulate.	2. simple, alternate, or lower opposite and upper alternate, or all opposite or whorled, exstipulate.
3. Inflorescence—cymose.	3. cymose.	3. racemose (raceme or spike) or cymose.
4. Flowers—regular, bisexual, hypogynous.	4. apparently regular, sometimes zygomorphic, bisexual, hypogynous.	4. irregular, bisexual, hypogynous.
5. Sepals—5, free or united, often persistent.	5. (5), persistent, often enlarging in fruit.	5. (5), more or less deeply 4-5 partite.
6. Petals—(5), funnel- or bell-shaped, twisted.	6. (5), rotate or funnel-shaped, plicate.	6. (5), usually personate, imbricate.

Convolvulaceae	*Solanaceae*	*Scrophulariaceae*
7. Stamens—5, unequal.	7. 5, but 2+2 in zygomorphic flowers.	7. usually 2+2, rarely 5 or 2.
8. Carpels—(2), medianly placed.	8. (2), obliquely placed.	8. (2), medianly placed.
9. Ovary—2-celled with 2 anatropous ovules in each or 4-celled with 1 ovule in each.	9. 2-celled or falsely 3-5-celled with many anatropous ovules in each.	9. 2-celled with many anatropous ovules in each.
10. Fruit—capsule, sometimes berry.	10. berry, sometimes capsule.	10. capsule, sometimes berry.

BIGNONIACEAE

General characters

Plants—trees or shrubs, often climbers. Leaves—usually opposite, simple or pinnately compound, often glandular, exstipulate. Inflorescence—cymose (dichasial cyme). Flowers—irregular, bisexual, hypogynous, bracteate. Sepals—(5), with 5 teeth or lobes, sometimes bilabiate (e.g., *Spathodea*) or truncate. Petals—(5),

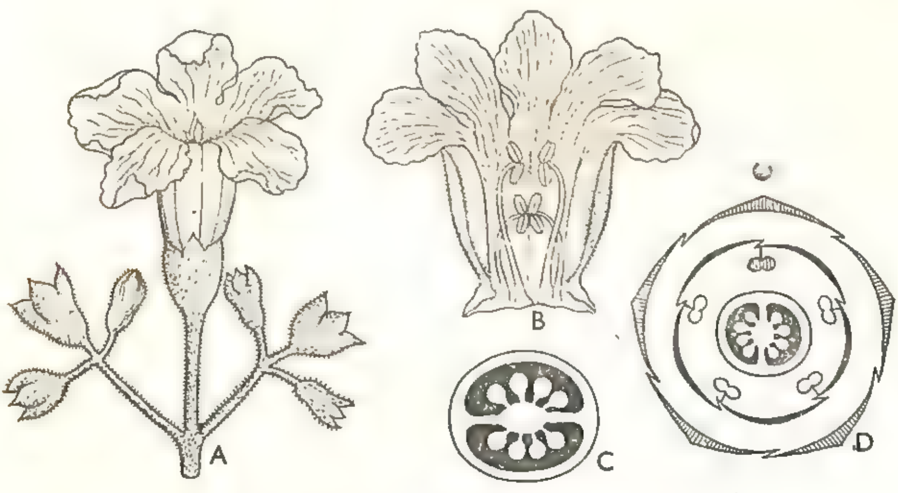


Fig. 663. Bignoniaceae (*Stereospermum suaveolens*).
A, Portion of an inflorescence; B, Corolla tube split open; C, T.s. of ovary; D, Floral diagram.

bell- or funnel-shaped rarely bilabiate, imbricate. Stamens—4, didynamous, with a posterior staminode or rarely perfect (e.g. *Oroxylum*), sometimes 2, inserted on the lower part of the corolla-tube, epipetalous; anther cells parallel or divaricate. Carpels—(2); ovary superior, usually 2-celled with axile placentation, sometimes 1-celled with parietal placentation (e.g., *Kigelia*) having numerous anatropous ovules; style terminal; stigma 2-lobed. Fruit—a 2-valved long capsule, sometimes fleshy and indehiscent (e.g., *Kigelia*, *Crescentia*, etc.). Seeds—numerous, *exalbuminous, usually winged.*

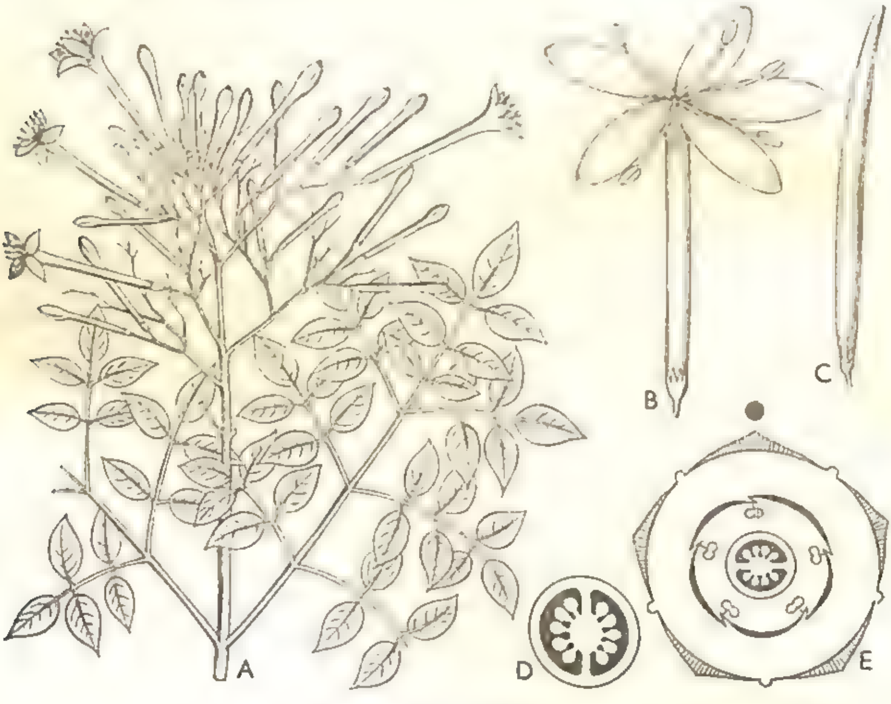


Fig. 664. Bignoniaceae (*Millingtonia hortensis*).
A, Portion of a flowering shoot; B, Flower; C, Fruit; D, T.s. of ovary; E, Floral diagram.

Number and distribution

This family consists of about 110 genera and 750 species which are chiefly distributed in the tropics.

KEY TO GENERA

A. Stamens 5 perfect, leaves 2-3 pinnate; capsule septifragal, calyx large coriaceous; corolla tube wide campanulate . . *Oroxylum.*

B. Stamens 4, perfect

(a) Capsule septifragal; leaves 2-3 pinnate; calyx small cupshaped; corolla long, slender .. .. *Millingtonia.*

(b) Capsule loculicidal; leaves 1-2 pinnate or rarely simple; calyx large; corolla tube short or long and much reduced at the mouth

(i) capsule with double wings at the margins; calyx large, swollen, campanulate .. .. *Pajanella.*

(ii) capsule not winged

(1) calyx tubular, campanulate, equally 5-toothed .. .. .. *Tecoma.*

(2) calyx ovoid and oblong, never equally 5-toothed; corolla tube long or short cylindric below and campanulate above .. *Dolichandrone.*

(3) calyx spathaceous: corolla tube ventricular; corolla irregular; deeply 3-5-lobed; capsule falcate or twisted .. .. .. *Heterophragma.*

(4) calyx truncate or shortly unequally lobed; capsule with thick spongy septum .. *Stereospermum.*

Fig. 665. Bignoniaceae (*Qescentia cujete*).
A, Portion of the trunk with foliage leaves and flowers; B, V.s. of a flower; C, Fruit; D, Seed.

Common plants

(1) *Oroxylum indicum* Vent., a small tree often planted on roadsides. (2) Indian Cork tree (*Millingtonia hortensis* L.), a tall tree often planted on roadside and gardens. (3) *Pajanella rheedei* DC. (4) Yellow Elder (*Tecoma stans* L.), a garden shrub. (5) *Dolichandrone spathaceae* K. Schum, a fairly tall tree. (6) *Heterophragma adenophyllum* Seems., a large tree. (7) *Bignonia venasta* Ker., a common garden climber with orange coloured flowers. (8) African tulip tree (*Spathodea campanulata*, Beauv.). (9) The Sausage tree (*Kigelia pinnata* DC.). (10) Calabash tree (*Crescentia cujete* L.) and (11) Jacranda (*Jacranda mimosifolia* D. Don.), are beautiful flowering trees. (12) Cat's claw (*Bignonia unguis-cati*), a slender climber, the terminal leaflets of which are modified into hook-like structures. (13) *Tabebuia rosea* DC., another tall tree with rosy-pink flowers. (14) *Stereospermum suaveolens* DC., *S. chelinoides*, very common tall trees. (15) Candle tree (*Parmentiuros cerifera* Seems.) can be found in the Indian Botanic Garden.

Affinity

This family is readily distinguished from other allied families by the structure of the fruit, and the conspicuous winged exalbuminous seeds.

Economic importance

This family is somewhat economically important. West Indian boxwood (*Tabebuia*) yields good quality of timber. The fruits of the calabash tree (*Crescentia cujete*) are used for begging bowls. Seeds of *Oroxylum* are used in medicine. *Oroxylum* and *Millingtonia* are used as roadside plantation. Species of *Spathodea*, *Crescentia*, *Kigelia*, *Jacranda*, *Bignonia* are ornamental plants.

PEDALIACEAE

General characters

Plants—annual or perennial herbs or undershrubs. Leaves—opposite or the uppermost ones sometimes alternate, simple, entire or lobed, exstipulate. Inflorescence—cymose, sometimes racemose (raceme). Flowers—irregular, bisexual, hypogynous. Sepals—5, sometimes 4, slightly united at the base. Petals—(5), oblique or slightly bilabiate, tubular below, imbricate. Stamens—2+2, didynamous or 2 (e.g., *Martynia*), epipetalous. Carpels—(2); ovary

superior, seated on a large fleshy or glandular disc, usually *4-celled*, sometimes 1- or 2-celled, with many or few anatropous ovules; stigma slightly 2-lobed; style slender. Fruit—capsule, or nut, often *beaked, or barbed*, or with wings. Seeds—albuminous.

Number and distribution

This family consists of 16 genera and about 50 species, mostly tropical.

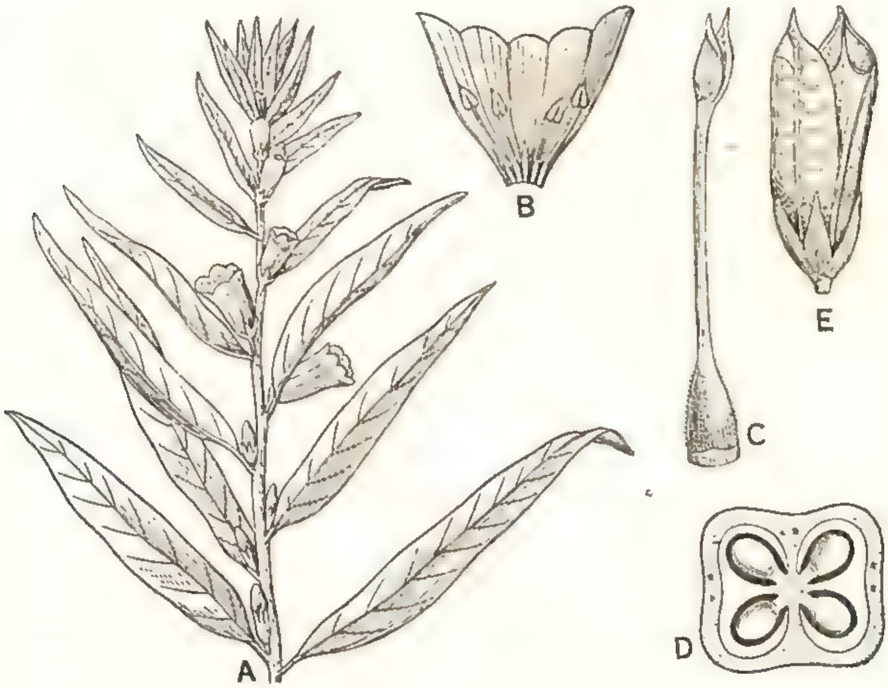


Fig. 666. Pedaliaceae (*Sesamum indicum*).
A, Portion of a flowering shoot; B, Corolla tube split open; C, Pistil; D, T.s. of ovary; E, Fruit.

Key to Genera

Anther-cells divariacate; ovary 1-celled; placenta parietal; capsule beaked; racemes terminal ... ... *Martynia*.

Anther-cells sub parallel; ovary 2-celled and spuriously 4-celled; placenta axile; capsule not beaked; fls. axillary *Sesamum*.

Common plants

(1) The Tiger's claw plant (*Martynia diandra* Glox. = *Martynia annua* L.), a tall coarse herb, very common on roadsides and near villages. (2) The Gingelly or Sesame (*Sesamum indicum* DC.), a herb commonly cultivated for the sake of oil.

Affinity

This family is related to Acanthaceae in the zygomorphy of flowers and nature of fruit. It resembles Solanaceae in the presence of false septa. Pedaliaceae is readily distinguished by the 4-celled ovary, and usually beaked or barbed fruits.

Economic importance

This family has got some economic importance. The seeds of *Sesamum indicum* yield the gingelly oil of commerce. *Ceratotheca triloba* is an ornamental plant.

LENTIBULARIACEAE

General characters

Plants—small annual or perennial herbs, growing in water or wet places. Leaves—alternate or in basal rosette, often dimorphic, the

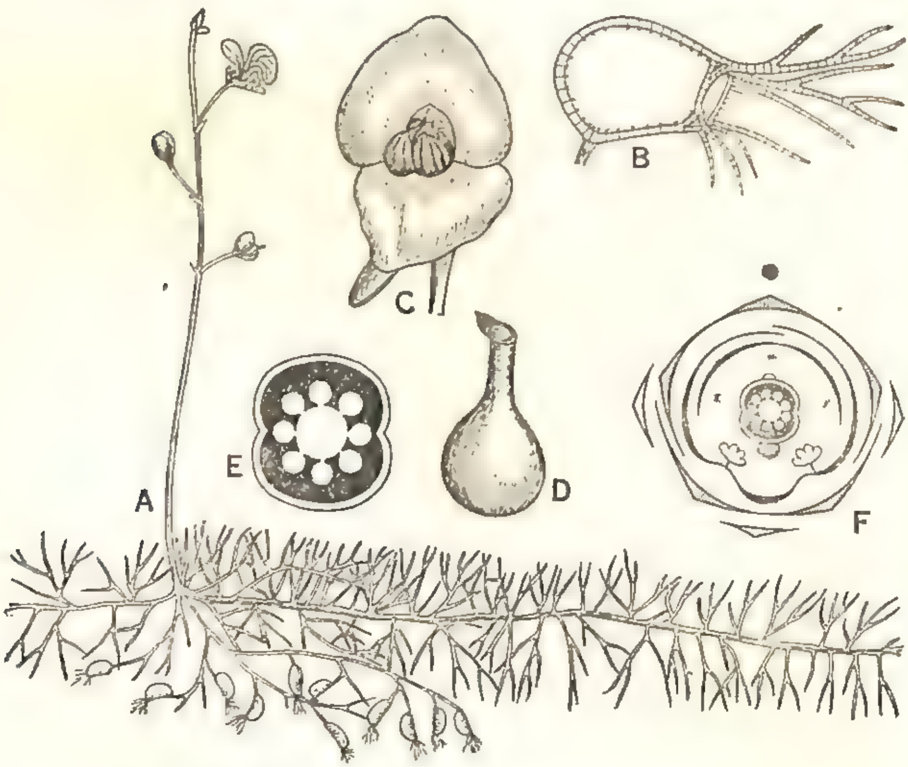


Fig. 667. Lentibulariaceae (*Utricularia stellaris*).
A, Portion of a flowering shoot; B, Bladder in section; C, Flower; D, Pistil; E, T s. of ovary; F, Floral diagram.

submerged ones are much dissected bearing small bladder-like appendages, while the aerial ones composing floating rosette. Inflorescence —raceme produced on a scape. Flowers—irregular, bisexual, hypogynous, bracteate. Sepals—(2-5), bilabiate, usually imbricate. Petals—(5), *bilabiate*, the lower lip much the larger and 3-lobed, sometimes personate. Stamens—2, epipetalous, adnate to the base of the corolla tube and alternating with the lower 3-lobed lip. Carpels—(2); ovary superior, 1-celled with many anatropous ovules on *free central placenta;* stigma bifid, unequal. Fruit—capsule. Seed—minute exalbuminous, with a poorly differentiated embryo.

Number and distribution

This family contains about 5 genera and 260 species which are mainly tropical and temperate.

Common plants

(1) *Utricularia stellaris* L., a common floating herb. (2) *U. flexuosa* Vahl., another common floating herb.

Affinity

This family is related to Scrophulariaceae in having zygomorphic flowers but readily distinguished by stamens 2, free central placentation and presence of tiny bladders.

Economic importance

This family is less important economically. Some species of butter-wort (*Pinguicula*) are used as ornamentals and a few species of bladder-wort (*Utricularia*) are grown in aquaria.

ACANTHACEAE

General characters

Plants—perennial herbs or shrubs, sometimes climbing, rarely trees (e.g., *Strobilanthus*), with *branches swollen at the nodes*. Leaves—opposite and decussate, simple, entire, often with *cystoliths*, exstipulate. Inflorescence—racemose (dense spike) or cymose, often with *copious bracts and bracteoles*. Flowers—irregular, bisexual, hypogynous, bracteate. Sepals—(5), often unequal, much reduced (e.g., *Thunbergia*), imbricate or valvate. Petals—(5), often *bilabiate*,

sometimes *oblique*, imbricate or twisted. Stamens—4, didynamous, sometimes 2 (e.g., *Justicia*, *Adhatoda*, etc.), epipetalous, sometimes 1-3 staminodes present; anthers sometimes spurred and hairy. Carpels—(2), medianly placed; ovary superior, *beaked* (prolonged but does not bear any ovule), 2-celled, with 2 or more anatropous ovules in each cell on the axile placenta; style simple, *terminal;* stigma often unequal, sometimes spoon-shaped. Fruit—usually a

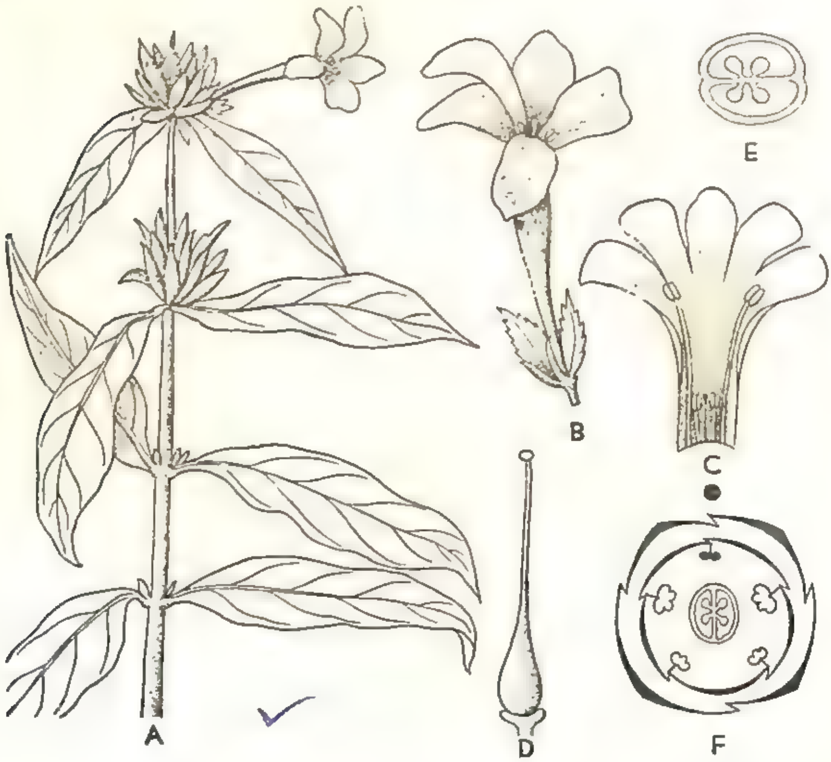


Fig. 668. Acanthaceae (*Barleria cristata*).
A, Portion of a flowering shoot; B, Flower; C, Corolla-tube split open; D, Pistil; E, T.s. of ovary; F, Floral diagram.

loculicidal capsule. Seeds—generally supported on a development (often hook-like) of the funicle (*jaculator*), exalbuminous. Embryo—*curved*, radicle pointed downwards.

Number and distribution

This family consists of about 240 genera and over 2,200 species which are commonly found in the tropical regions.

Key to Genera

A. Corolla-lobes imbricate in bud; ovules numerous in two long rows; seeds mounted in papilla

(*a*) Stamens 2; calyx 4-sect; herbaceous bracts .. *Nelsonia.*

(*b*) Stamens 4; calyx 5-partite .. .. .. *Ebermaiera.*

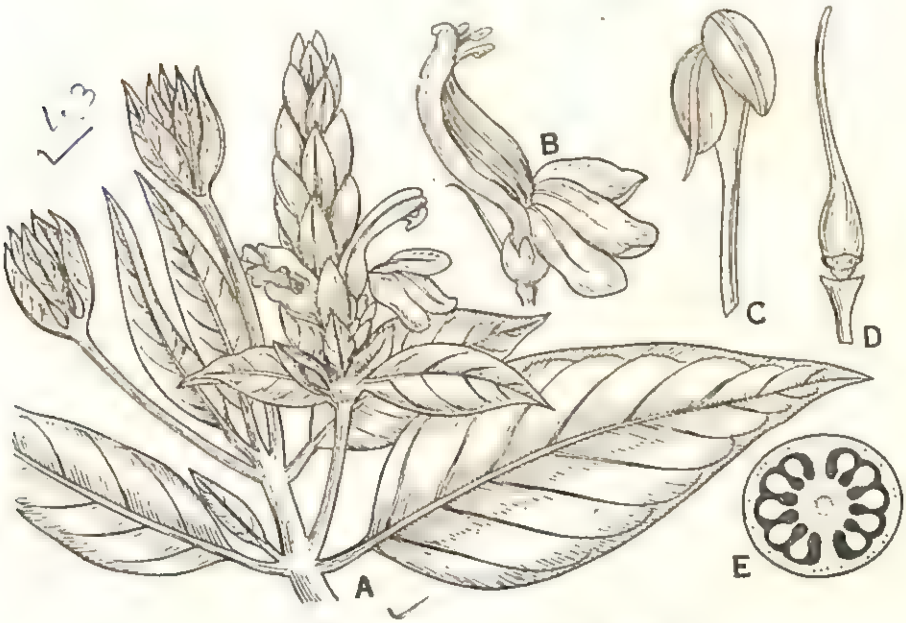


Fig. 669. Acanthaceae (*Adhatoda vasica*).
A, Portion of a flowering shoot; B, Flower; C, Stamen; D, Pistil; E, T.s. of ovary.

B. Corolla-lobes imbricate; jaculators curved; anthers 2-1-celled, often spurred at the base

(*a*) Ovules 3-10 in each cell; capsule more or less few-seeded, compressed at right angles to septum; fls. panicled .. .. *Andrographis.*

(*b*) Ovules 2-1 in each cell; corolla-lobes subequal; stamens 4, of which 2 are small or obsolete

(*i*) Anthers 2-celled .. .. .. *Barleria.*

(*ii*) Anthers 1-celled .. .. .. *Crossandra.*

(*iii*) Anthers 2-celled, all equal, calyx deeply 5- or 4-lobed .. .. *Lepidagathis.*

(*iv*) Anthers 2-celled; stamens 4; corolla tube long; limb enlarged .. .. .. *Asystasia.*

(*v*) Anthers 2-celled; stamens 2; placenta originating from the base

(1) Single-sided bracts, spicate; short-stalked capsule .. .. .. *Rungia*.

(2) Clustered bracts, 2 unequal; fls. shortly pedicellate; club-shaped capsule; calyx 5-partite .. .. .. *Dicliptera*.

(*vi*) Anthers 2-celled, one placed above the other, lower minutely spurred at the base; herbs or shrubs .. .. *Justicia*.

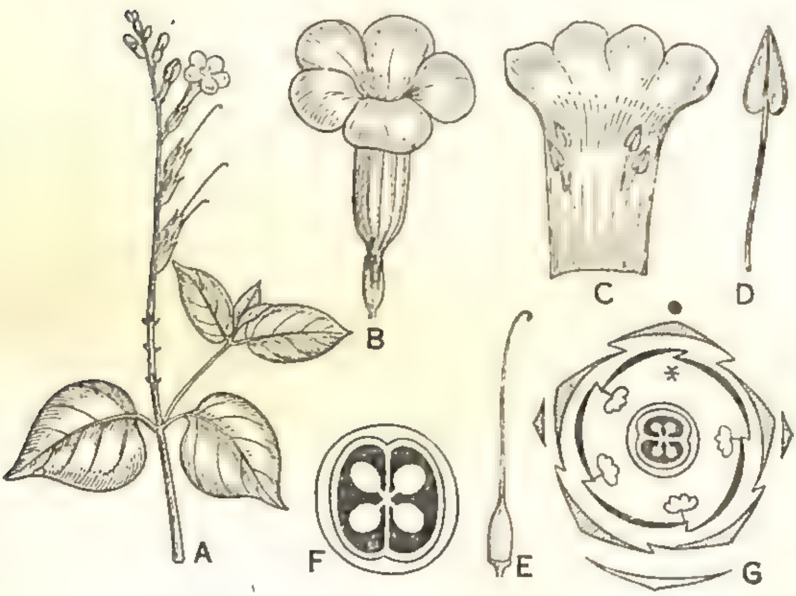


Fig. 670. Acanthaceae (*Asystasia gangetica*).
A, Portion of a flowering shoot; B, Flower; C, The same split open; D, Stamen; E, Pistil; F, T.s. of ovary; G, Floral diagram.

(*vii*) Anthers 2-celled, apiculate, scarcely spurred; corolla 2-lipped, short-tubed; bracts leafy; placentae not originating from the base of the capsule .. .. *Adhatoda*.

(1) Fls. long, narrow, clustered; bracts narrow, small; plants usually shrubs .. .. *Rhinacanthus*.

(2) Fls. in axillary or terminal clusters; bracts larger than the bracteoles in opposite valvate pairs; corolla rose or purple; plants spreading herbs .. .. .. *Peristrophe*.

(*c*) Ovules 2 in each cell; stamens 2

(*i*) Corolla cylindric, widened at the base; anther-cells parallel, equal with widened connective .. *Eranthemum.*

(*ii*) Corolla tube long, filiform; anther-cells parallel, subequal; large bracts imbricated .. .. *Ecbolium.*

C. Corolla-lobes twisted in bud

(*a*) Stamens 4, didynamous; bracts large, foliaceous; ovules in collateral pairs in each cell; fruit beaked capsule; jaculator absent: plant usually a climber with yellow or blue fls. .. .. *Thunbergia.*

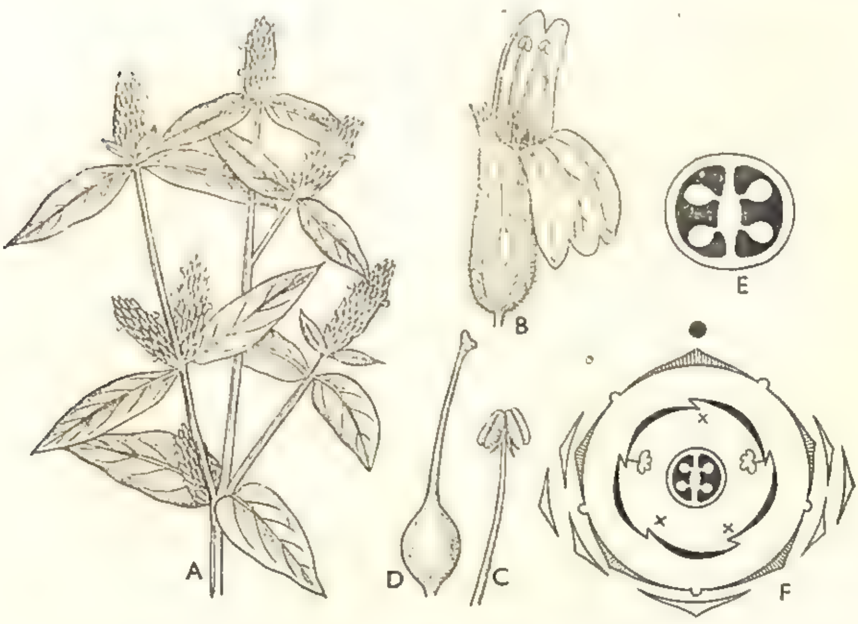


Fig. 671. Acanthaceae (*Justicia simplex*).
A, Portion of a flowering shoot; B, Flower; C, Stamen with appendage; D, Pistil; E, T.s. of ovary; F, Floral diagram.

(*b*) Stamens 4, didynamous; seeds mounted on jaculator; style 2-fid, one lobe often suppressed

(1) Ovules 3-12 in each cell

(*i*) Corolla 2-lipped; fls. sessile, axillary, lower leaves often toothed; jaculator not hooked .. .. .. *Cardenthera.*

(*ii*) Corolla 2-lipped; fls. subsessile, axillary; leaves entire; jaculator hooked; capsule narrow; spinescent herb .. .. *Hygrophila.*

(*iii*) Corolla regular, 5-lobed; large bracteole; stamens muticous; clavate capsule with solid base .. .. *Ruellia.*

(*vi*) Corolla 5-lobed; bracteole small or absent; fls. capitate; capsule with seeds from the base .. .. *Hemigraphis.*

Fig. 672. Acanthaceae (*Andrographis paniculata*).
A, Portion of a shoot; B, Flower; C, Corolla tube split open; D, Fruit; E, L.s. of the same; F, T.s. of ovary.

(2) Ovules 2 in each cell

(*i*) Corolla 5-lobed; stamens 4 or 2; anthers muticous; placenta from the base of the capsule .. .. .. *Strobilanthes.*

(*ii*) Corolla 5-lobed, slightly unequal; stamens 4, didynamous; anthers 2-celled, parallel, base mucronate; placenta from the base of the capsule .. .. .. *Phaylopsis.*

D. Corolla-lobes short, upper lip reduced, lower one 3-lobed; ovules 2 in each cell; jaculator curved and hardened; anterior filaments with process .. .. .. *Acanthus.*

Common plants

(1) *Adhatoda vasica* Nees., a common densely growing erect shrub. (2) *Barleria prionitis* L., a shrub, commonly found in bushes with two prolonged thorns at each node. (3) *Barleria cristata* L., an erect undershrub. (4) *Hygrophila spinosa* T. And. = *Asteracanthus longifolia* Nees., an erect highly spinous marshy herb extensively used as a remedy for diarrhoea; *H. phlomoides* Nees., an erect herb without any spine, commonly found in wet places. (5) *Andrographis paniculata* Nees., a common herb with square stems used as a febrifuge and liver tonic; *A. echioides* Nees., common in waste places and on old

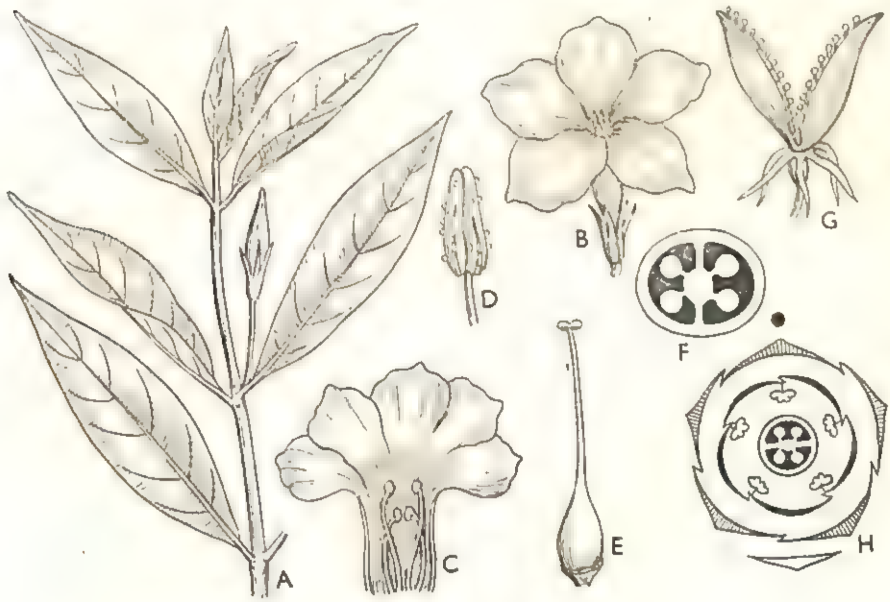


Fig. 673. Acanthaceae (*Ruellia tuberosa*).
A, Portion of a plant; B, Flower; C, Corolla split open: D, Stamen; E, Pistil; F, T.s. of ovary; G, Fruit dehiscing; H, Floral diagram.

brick walls. (6) *Justicia gendarussa* L., often planted in gardens. (7) *J. simplex* Don., *J. diffusa* Willd. and *J. procumbens* = *Rostellularia procumbens* Nees., are common weeds; *J. betonica* L., an erect shrub with pale violet flowers, often planted in gardens. (8) *Ruellia prostrata* Lamk. = *Dipterocanthus prostratus* Nees., and *R. tuberosa* L. = *Dipterocanthus tuberosus* Nees., very common in and about gardens. (9) *Cardenthera triflora* Ham., a weed of marshy places. (10) *Ecbolium linneanum* Kurz., a small shrub commonly found in bushes and roadsides. (11) *Nelsonia campestris* R. Br., a diffuse herb found on grassy

(iii) Ovules many, ascending on projecting placentae; heads ebracteated; climbers with hooked peduncles .. .. *Uncaria.*

B. Fls. borne in terminal dense panicled cyme

(i) Corolla-lobes twisted in bud; fruit capsular, 2-celled, angular; seeds wingless; usually shrubs or trees .. .. .. *Wendlandia.*

(ii) Corolla-lobes valvate with inflexed and crisped margins; fruit 2 dorsally compressed 1-seeded pyrenes; seeds much compressed; slender twining shrubs, foetid when bruised .. *Paederia.*

C. Fls. solitary or at the tip of forked branches; corolla funnel-shaped, 5, valvate; calyx-limb 5, globose, persistent; fruit indehiscent 2-celled, each with many ovules; an annual herb, prostrate and rooting at the nodes .. .. *Dentella.*

D. Fls. solitary or in capitate or panicled cyme

(a) Fruit oblong, subglobose-orbicular, 2-, rarely 4-celled, usually dehiscent loculi- or septi-cidal capsule, with contiguous calyx-teeth; seeds usually angular .. .. *Hedyotis.*

(b) Fruit oblong 2-celled capsule; corolla-lobes 4; stipules bristly non-entire, fls. in cyme; calyx-teeth remote

(i) Seeds minute and angular; fls. in paniculate cyme .. .. *Oldenlandia.*

(ii) Seeds globose or plano-convex with a cavity on the ventral surface .. .. .. *Anotis.*

(c) Fruit a fleshy berry; seeds many, small

(i) Corolla valvate; terminal inflorescence; calyx with one limb forming coloured flag (flag apparatus) .. .. *Mussaenda.*

(ii) Corolla imbricate, rarely twisted; stamens inserted at the base of the corolla tube; inflorescence terminal .. .. .. *Hamelia.*

(iii) Corolla imbricate; stamens inserted at the mouth of the corolla tube; inflorescence axillary

(1) Ovary 1-celled, many-ovuled; stigma fusiform .. .. .. *Gardenia.*

(2) Ovary 2-celled, many-ovuled; stigma fusiform .. .. .. *Randia.*

(3) Ovary 2-celled; few-ovuled; style arm bifid; fls. in axillary spikes .. .. *Petunga.*

(*iv*) Corolla-lobes twisted; stipules interpetiolar

(1) Fls. in long corymb

Petals 5; bracts thin, membraneous .. *Pavetta.*

Petals 4; bracts coriaceous .. .. *Ixora.*

(2) Fls. axillary, solitary or fascicled; style arms 2, linear; petals 4-5 .. .. *Coffea.*

(*v*) Corolla-lobes valvate; stipules interpetiolar

(1) Fls. in dense heads; fruit a globose or oblong solid mass; erect shrubs or small trees .. .. *Morinda.*

(2) Fls. free, densely panicled; fruit capsular, 5-valved at the apex; stigma papillate, 5-fid .. .. *Hamiltonia.*

(3) Fls. free; setaceous stipule, connate with the petiole into toothed cup; fruit of 2 separable cocci; leaves opposite

Ovules pendulous; dorsally compressed seeds; fruit small .. .. *Knoxia.*

Ovules attached to ovarian septum; seeds oblong; fruit small, crustaceous, one or both dehiscent into separate cocci .. .. .. *Spermacoce.*

(4) Leaves whorled; stipules foliar; fruit of 2 leathery or fleshy lobes .. .. *Rubia.*

E. Fls. in axillary fascicle; corolla-lobes valvate with a ring of deflexed hairs inside and a smooth or villous throat; disc swollen; ovule solitary, pendulous; fruit drupaceous

(*a*) Ovary 2-celled; fls. very small, 4-merous; plants usually erect, sometimes climbing .. .. *Canthium.*

(*b*) Ovary 3-5-celled; fls. 5-merous; plants always erect .. .. *Vangueria.*

(*c*) Ovary 2-celled; fls. 5-merous, plants shrubs .. *Psychotria.*

Range of floral structures

Flowers are generally bisexual, regular, tetra- or penta-merous; calyx with valvate aestivation; corolla usually funnel-shaped, salver-shaped or rotate with valvate, imbricate or contorted aestivation. Stamens inserted on the corolla-tube, 2-celled. Carpels (2), sometimes provided with a fleshy disc; ovary inferior, 1-many-celled, usually 2-chambered, with numerous to 1 anatropous ovules in each; style filiform, bifid or multifid.

Variation in the floral structure is also remarkable in the different genera. Regular flowers occur in *Oldenlandia*, *Rondeletia*, *Cinchona*, *Ixora*, *Hamelia*, but zygomorphy of flower is found in *Posoqueria*, *Henriquezia*.

Unisexuality is often noted in some genera. The dioecious flowers are found in *Anthospermum*, *Coprosma*.

Calyx becomes enlarged and leaf-like, as in *Mussaenda*. *Warscewiczia* and also in *Nematostylis*.

Ovary is generally inferior, but semi-inferior ovary is also found to occur in *Synaptantha;* the superior ovary is sometimes found in the genus *Gaertnera* (Tropical Africa and India) and *Pagamea* (Brazil, Guiana).

Variations in the number of chambers of ovary, number of ovules in each chamber, and attachment of ovules also occur in many genera. Exceptions to the 2-chambered ovary with parietal placentation occur in the genera *Gardenia*, *Oldenlandia*, *Rondeletia*, *Cinchona; Pavetta* is uniovulate with the ovule sunken in the fleshy funiculus. The genera *Vangueria*, *Knoxia*, *Ixora*, *Hamelia*, etc., represent the uniovulate one-chambered ovary.

The attachment of the ovules either at the base of the ovary or to the septum is variable in different genera. Basal attachment of ovules is found in the genera *Psychotria*, *Uragoga*, *Hydnophytum*, *Myrmecodia*, *Paederia* and others. Septal attachment of ovules is noted in some genera, such as, *Galium*, *Asperula*, *Rubia*, *Crucianella* and others.

Common plants

(1) *Ixora coccinea* L. and *I. parviflora* Vahl. = *I. arborea* Roxb. are common garden shrubs. (2) *Oldenlandia corymbosa* L., *O. umbellata* L. and *O. paniculata* L., are common weeds in rice fields. (3) *Anthocephalus cadamba* Miq. = *A. indicus* Rich., a common large tree. (4) *Adina cordifolia* Hook. f. (5) Cape jasemine (*Gardenia florida* Willd. = *G. jasminoides* Ellis.), much-branched shrub grown in gardens. (6) *Vangueria spinosa* Roxb. = *Meyna laxiflora* Robins, spinous tree. (7) *Paederia foetida* L., a foetid slender twining shrub, the leaves of which are reputed as a good stamochic. (8) Indian madder (*Rubia tinctorum* L.), a climbing herb with big stipules. (9) *Mussaenda frondosa* Hook., a small shrubby plant, one of the calyx-lobes of which grows out into a large white leaf-like expansion, common in nurseries. (10) *Catesbaea spinosa*, a highly spinous herb with showy white

tubular flowers which hang vertically downwards; very common in the Indian Botanic Garden. (11) Coffee plant (*Coffea arabica* L.), usually cultivated in Southern India for coffee. (12) Cinchona plant (*Cinchona succirubra* Pavon ex Klotzsch, *C. officinalis* L., *C. ledgeriana* Moens, *C. calisaya* Wedd.), cultivated on the hills for its bark which

Fig. 676. Rubiaceae (*Oldenlandia corymbosa*).
A, Portion of a flowering shoot; B, Flower; C, Corolla split open; D, Pistil; E, T.s. of ovary; F, Fruit; G, Floral diagram.

yields quinine. (13) Ipecac (*Psychotria ipecacuanha* Stocks), a medicinal plant with moniliform roots. (14) *Dentella repens* Forst., a common weed. (15) *Morinda citrifolia* L., a garden plant which produces multiple fruit. (16) *Randia dumetorum* Lamk., a large shrub with spines; *R. uliginosa* DC., a small tree that can be found in Indian Botanic Garden. (17) *Hamelia patens* Jacq., a common garden plant.

(18) *Stephegyne parvifolia* Korth. = *Mytragyna parvifolia* Korth., often mistaken for *Anthocephalus*. (19) *Canthium angustifolium* Roxb., a spreading shrub of the Sundribans. (20) *Hedyotis auricularia* L., a herb.

Fig. 677. Rubiaceae (*Catesbaea spinosa*).
A, Portion of a flowering shoot; B, Corolla split open; C, Pistil; D, T.s. of ovary; E, Floral diagram.

(21) *Uncaria macrophylla* Wall., a strong climber. (22) *Wendlandia exserta* DC., a small crooked tree. (23) *Anotis calycina* Hook. f., a slender annual herb. (24) *Petunga roxburghii* DC., an evergreen

shrub of the Sundribans. (25) *Pavetta indica* L., a small tree. (26) *Knoxia corymbosa* Willd., a common erect annual. (27) *Spermacoce hispida* L. = *Borreria hispida* K. Schum., a common perennial herb. (28) *Hamiltonia suaveolens* Roxb., a small shrub.

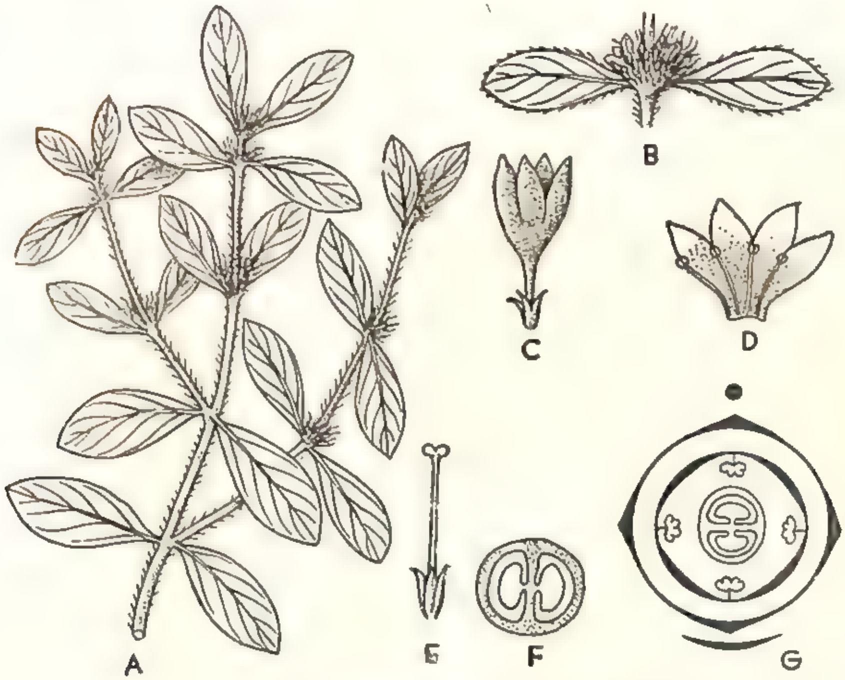


Fig. 678. Rubiaceae (*Spermacoce hispida*).
A, Portion of a flowering shoot; B, Inflorescences in the axils of opposite leaves; C, Flower; D, Corolla split open; E, Pistil; F, T s. of ovary; G. Floral diagram.

Affinity

This family can be traced phylogenetically from Umbelliferae, particularly allied to Cornaceae, in the morphological aspects, such as, presence of interpetiolar stipules, cymose umbel-like inflorescence, suppression of calyx, epigyny, etc. The family is also allied to Adoxaceae, Caprifoliaceae under the Order Rubiales. Rubiaceae is apparently related to Compositae. The derivation of head can be traced from the head-like inflorescence of some members of Rubiaceae and Dipsaceae.

Economic importance

This family is of economic importance. Coffee is obtained

from *Coffea arabica*. Quinine is obtained from the bark of Cinchona. *Paederia*, *Oldenlandia* and *Anthocephalus* are of medicinal importance. *Psychotria ipecacuanha*, which is the source of 'vinum ipecac', is also a valuable medicinal plant: the alkaloid '*emetin*' is extracted from the plant. The roots and branches of *Rubia tinctoria* yield a red dye. Some plants are ornamentals, such as, *Gardenia*, *Rubia*, *Ixora*, *Knoxia*, *Stephegyne*, *Catesbaea*, *Morinda*, *Mussaenda*, *Galium*, *Hamelia*, *Randia*, etc.

ORDER 9. CUCURBITALES

Flowers tetracylic, actinomorphic, pentamerous, unisexual, epigynous. Petals often connate, seldom free. Stamens often united forming synandrium. Ovary tricarpellary, inferior. Seeds exalbuminous.

According to Engler this Order consists of only one family, Cucurbitaceae. Bentham and Hooker have placed Cucurbitaceae in the cohort Passiflorales under the subclass Polypetalae, which is an exceptional case in the aforesaid subclass. In Hutchinson's system this Order (30th Order) consists of 4 families and has been placed under Archichlamydeae.

CUCURBITACEAE

General characters

Plants—climbing or procumbent herbs with *extra-axillary*, simple or branched tendrils, monoecious or dioecious (e.g., *Trichosanthes dioica*, *Bryonia dioica*) often with 5-angled stems. Leaves—alternate, simple, often lobed, palmi-veined, exstipulate. Inflorescence—cymose. Flowers—*unisexual*, regular, epigynous, usually yellow or white. Sepals—(5), imbricate. Petals—(5), inserted on the calyx-tube, bell-shaped or rotate. Stamens—5 in the male flowers, usually all united into a column (*syngenesious*), or appear to be 3 owing to 4 of them uniting in two pairs; anthers extrorse, straight or sinuous; one anther always 1-celled, the other 2-celled. Carpels—in the female flowers, (3); ovary *inferior*, 1-celled, but sometimes becomes spuriously 3-celled owing to the projection of the *parietal placentae* towards the centre; style one, short and thick, generally divided into 3 branches with a horse-shoe shaped stigma on each branch.

Fruit—usually a *pepo*, sometimes berry. Seed—exalbuminous. Embryo—straight with large oily cotyledons.

Number and distribution

This family consists of about 100 genera and 850 species which are commonly found in the tropics.

Fig. 679. Cucurbitaceae (*Cucurbita maxima*).
A, Portion of a shoot; B, Staminate flower; C, Pistillate flower; D, Androecium; E, Pistil; F, T.s. of ovary; G, Floral diagram of staminate flower; H, The same of pistillate flower.

KEY TO GENERA

Female fls. usually single; ovules pendulous or horizontal

A. Anther-cells 'S'-shaped or folded. Corolla rotate or campanulate, divided or nearly so into 5 petals above.

(*a*) Tendril divided

(*i*) Fls. white; petals fimbriated at the margin; seeds many .. .. .. *Trichosanthes.*

(*ii*) Fls. large, white; petals entire; anthers included; petiole with 2 glands .. .. *Lagenaria.*

(*iii*) Fls. pale yellowish-white; petals fimbriated; seeds many .. .. .. *Hodgsonia.*

Economic importance

This family is of considerable economic importance. A large number of plants produce edible fruits. Among them are *Trichosanthes*, *Cucumis*, *Benincasa*, *Cucurbita*, *Citrullus*, etc. Some plants are of medicinal importance, e.g., Colocynth and Bryony. *Luffa echinata* produces a bitter alkaloid which is used as a remedy for dropsy. Some plants are ornamentals, such as, *Echallium*, *Sechium*, *Cephalandra* and others.

ORDER 10. CAMPANULATAE

Flowers bisexual or unisexual by suppression of one of the essential whorls, actinomorphic or zygomorphic, pentamerous, epigynous, mostly aggregated in heads. Stamens syngenesious. Carpels usually three. Ovary inferior, usually one-celled with a single ovule.

According to Engler this Order contains 6 families, viz., Campanulaceae, Compositae, etc.; he regarded Compositae as the most highly evolved family, and hence, it has been placed last in the subclass Metachlamydeae. Bentham and Hooker have placed Compositae in the beginning of Gamopetalae, next to Rubiaceae under the cohort Asterales. Hutchinson like Bentham and Hooker has placed Compositae along with other 4 families under the Order Asterales (67th Order).

COMPOSITAE

General characters

Plants—usually herbs, sometimes shrubs. Leaves—alternate (sometimes opposite), simple or variously lobed, exstipulate. Inflorescence—*capitulum* (excepting *Caesulia*, *Layascea* and *Echinops*), homogamous (e.g., *Launaea*, *Emilia*, *Vernonia*, etc.) or heterogamous, surrounded by an *involucre* of bracts. Florets of the capitulum—sessile, bisexual or unisexual, or the outer (ray-florets) female or neuter, palaeated or non-palaeated. Sepals—absent or *modified into pappus*. Petals—(5), tubular, ligulate or bilabiate, valvate. Stamens—5, *syngenesious*, epipetalous. Carpels—(2); ovary *inferior*, 1-celled with one ascending, anatropous ovule borne on basal placenta; stigma bifid. Fruit—*cypsella*, often crowned by persistent pappus. Seed—exalbuminous. Embryo—straight.

Number and distribution

This family consists of about 950 genera and probably 20,000 species which are cosmopolitan.

Fig. 681. Compositae (*Eupatorium odoratum*).
A, Portion of a flowering shoot; B, Inflorescence; C, Flower; D, The same with petals removed; E, Pistil.

KEY TO GENERA

A. Florets all tubular and hermaphrodite, corolla never yellow, no rays, bracts in many series
  (*a*) Leaves alternate, heads many-flowered
    Pappus absent, achenes 4-5-angled .. .. *Ethulia.*
    Pappus short, falling off early, achenes 10-ribbed .. *Centratherum.*
    Pappus of many long hairs and bristles, achenes angled or ribbed or not so, but rounded .. *Vernonia.*

Rigid herbs, heads of 2-5 florets, clustered in dense masses, corolla 4-lobed, pappus of shining bristles, cypsella 10-ribbed .. .. .. *Elephantopus.*

(*b*) Leaves opposite

Smooth or glandular herbs, bracts in 1 or 2 series, achenes 5-ribbed, glandular, pappus hairs few or short, flowers white .. .. .. *Adenostemma.*

Flowers small, pale purple; leaves opposite but uppermost ones sometimes alternate; bracts 2-3-seriate, linear; cypsella 5-angled, pappus with 5-many scales .. .. .. *Ageratum.*

Herbs or undershrubs; leaves opposite, rarely alternate; bracts several seriate; pappus hairs rigid, anther-tip appendiculate .. .. *Eupatorium.*

Head 4-flowered; bracts of involucre 4; leaves long-petioled, cordate; a twining plant, scandent and often attaining heights of trees; flowers white .. .. *Mikania.*

B. Florets tubular and hermaphrodite, corolla yellow

Prostrate herb forming patches; leaves alternate, pinnatifid; flowers in round flat-topped heads, heterogamous, not rayed .. .. *Grangea.*

Annual herbs; leaves radical; flower-head heterogamous, rayed; ray florets female, never yellow, 2-more seriate .. .. .. *Erigeron.*

Leaves alternate, usually toothed or lobed, glandular; pubescent woody herbs; flower-heads heterogamous, purple, rosy or commonly yellow; outer florets female, many seriate, filiform; inner florets hermaphrodite, few; anthers sagittate at the base with slender tails .. .. *Blumea.*

Leaves alternate, decurrent, toothed; low-branched annuals with winged stems; flower-heads disciform, small, heterogamous; pappus absent .. *Sphaeranthus.*

Leaves alternate, entire; hoary or woody herbs; florets all fertile in corymbose leafless heads or leafy spikes or clusters .. .. .. *Gnaphalium.*

Glabrous marsh herbs; leaves alternate, serrulate, dilated into a broad stem-clasping base; stem purple; flower-heads each 1-flowered; pappus absent .. .. *Caesulia.*

Annual coarse herbs; leaves alternate, toothed, heart-shaped or 3-lobed; heads 1-sexual:

Female florets apetalous, 2-together, united with the involucre to form a 2-beaked utricle covered with hooked spines; male florets many in upper globular heads .. .. .. *Xanthium.*

C. Flower-heads rayed, leaves opposite

Leaves pinnatisect; pappus present; heads large showy, involucre of bracts fused, cylindrical and green .. .. *Tagetes.*

Leaves quite entire; heads large, rayed; involucre of bracts 3- or more-seriate, imbricate, gradually shorter from within outwards; capitulum large, showy .. .. *Zinnia.*

Marsh herb used in kitchen; leaves sessile; ray florets many-seriate, involucre of bracts in four pairs *Enhydra.*

Small herbs; capitulum small, peduncled, white, bracts in one or two series, outer large; disc florets 4-toothed .. .. *Eclipta.*

A procumbent herb growing in wet places near ponds or shrub, sometimes climbing; ray florets large, yellow, female, fertile; outer bracts of involucre 3-5, herbaceous, inner dry; pappus united at the base .. .. .. *Wedelia.*

Pappus scales free from the base, ray florets large, yellow, sterile—

Leaves always alternate, entire or toothed; capitulum large; bracts 2-many-seriate; corolla of tubular florets elongated, enlarged and 5-fid .. *Helianthus.*

Leaves opposite, ovate-lanceolate; capitula small, ovoid and yellow; cypsella of ray florets usually ciliate .. .. *Spilanthes.*

Leaves opposite or upper alternate; achene without pappus but crowned with base of corolla and almost 4-cornered .. .. .. *Guizotia.*

Annual branched herb; leaves opposite, petioled, toothed; flower-heads very small, yellow, axillary terminal, heterogamous and rayed; calyx and corolla of ray florets 2-3-toothed, tubular; corolla 4-toothed; cypsella of ray florets with 2-lacerated wings; pappus represented by spines *Synedrella.*

Tall annual herbs; leaves opposite, 2-3-pinnatisect or lobed or entire; capitulum white, pink or yellow, long-stalked, rayed, heterogamous; ray florets 1-seriate, neuter; bracts of involucre 2-seriate, united below; petals of ray florets united, ligulate; pappus 2 or 4, persistent .. .. *Cosmos.*

A weak, straggling perennial herb; leaves opposite, pinnatisect, segments few and narrow; capitulum long-stalked, rayed, heterogamous, bracts few-seriate; ray florets yellow, corolla bilabiate or ligulate with a large 3-fid or 3-partite outer and a small 2-fid or obsolete inner lip; pappus of short feathery bristle .. .. .. *Tridax*

Strong smelling herbs or shrubs; leaves alternate, 1-3-pinnatisect or entire or serrate; flower-heads small, greenish white or greenish yellow .. *Artemisia.*

Annual or perennial herb; leaves alternate, pinnately lobed or entire; capitulum large, showy on long peduncles, rayed, or sometimes homogamous from abortion of rays; ray florets female, 1-seriate; disc florets hermaphrodite; bracts of involucre many-seriate; pappus of short scales may be present .. .. *Chrysanthemum.*

Thistle-like herbs: leaves and involucre of bracts spinescent—

Flower-heads 1-flowered, crowded into spherical , masses, greenish white.. .. .. *Echinops.*

Flower-heads many-flowered, separate; flower hermaphrodite or by abortion 1-sexual; cypsella 4-angled, ribbed; pappus-hairs feathery .. *Cnicus.*

Herbs with milky juice, leaves radical or alternate, branches divaricate, sometimes spinescent—

Flowers blue .. .. .. *Chicorium.*

Flowers yellow—

Cauline leaves stem-clasping and auricled, flower-heads terminal

Achenes not beaked, compressed, many-ribbed *Sonchus.*

Achenes beaked .. .. .. *Lactuca.*

Annual weeds with long leaves, radical leaves crowded, petioled, entire or lyrate; cauline leaves often auricled and stem clasping—

Heads homogamous, florets purple .. .. *Emilia.*

Heads heterogamous, florets all yellow .. *Senecio.*

Thistle-like herbs; leaves alternate, white-veined above, sinuately lobed; lobes and teeth spinescent—

Flower-heads homogamous, terminal, large, nodding; bracts spinescent, fimbriate .. *Silybum.*

Annual milky herbs; leaves radical or cauline, often stem-clasping, spinose, toothed; flower-heads yellow, homogamous, ligulate, bell-shaped—

Perennial glabrous herbs with yellow juice .. *Launaea.*

Common plants

(1) Sunflower (*Helianthus annuus* L.). (2) Marigold (*Tagetes patula* L.). (3) Chrysanthemum (*Chrysanthemum coronarium* L.). (4) Garden zinnia (*Zinnia elegans*, *Z. pauciflora* L.). (5) Lettuce (*Lactuca sativa* L.), used as a salad. (6) *Enhydra fluctuans* Lour., commonly found in marshes, used as a vegetable and reputed

to induce sleep. (7) Jerusalem Artichoke (*Helianthus tuberosus* L.), cultivated for its tubers. (8) Niger seed (*Guizotia abyssinica* Cass.) yields an oil much used for adulterating purpose. (9) Safflower (*Carthamus tinctorius* L.), cultivated in cold weather for the orange dye from the petals and for oil from the seeds. (10) Climbing hemp weed (*Mikania scandens* Willd.), a climber. (11) *Tridax procumbens* L., very common in grassy waste lands and old walls, bearing cream-coloured flower-heads on long stalks during the

Fig. 682. Compositae (*Mikania scandens*).
A, Portion of a flowering shoot; B, Inflorescence; C, Floret; D, The same split open showing syngenesious stamens; E, Pistil; F, L.s. of ovary; G, Floral diagram.

dry season. (12) *Blumea lacera* DC., a very common annual weed with yellow flowers. (13) Iron weed (*Vernonia cinerea* Less.), another common weed with purplish flowers. (14) *Vernonia anthelmentica* Willd., a medicinal plant. (15) *Eclipta alba* Hassk. = *E. prostrata* L., also a common weed, the juice of the leaves of which is used in tattooing. (16) *Eupatorium ayapana* Vent., a medicinal plant, the leaves of which are reputed as a specific for stopping internal haemorrhage; *E. odoratum* L., a common weed. (17) *Wedelia calendulacea* Less., a medicinal plant, the leaves of which are used for promoting the

growth of hair. (18) *Adenostemma viscosum* DC., a common weed. (19) *Ageratum conyzoides* L., Elephant's foot (*Elephantopus scaber* L.), *E. spicatus* L., Milk-thistle (*Sonchus oleraceus* L., *S. asper* Vill., *Sphaeranthus indicus* L., *Cnicus arvensis* Hoffm. and *Emilia sonchifolia* DC. are common weeds. (20) *Senecio nudicaulis* Ham., *Caesulia axillaris* Roxb. and *Crepis japonica* Benth., are common in the rice fields. (21) *Dahlia*, *Cosmos*, Daisy, *Aster*, *Calendula*, *Gallardia* are common garden plants. (22) *Grangea maderaspatana* Poir., generally found on road-sides, dry fields and waste places. (23) *Gnaphalium indicum* L. and *G. luteoalbum* L., commonly found in dry fields. (24) Common cocklebur

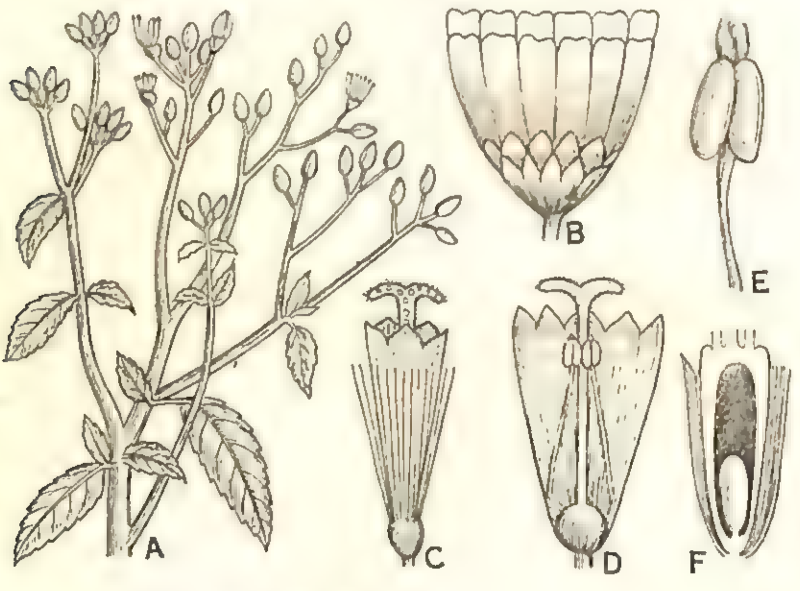


Fig. 683. Compositae (*Ageratum conyzoides*).
A, Portion of a flowering shoot; B, Capitulum; C, Floret; D, The same split open; E, Stamen; F, V.s. of ovary.

(*Xanthium strumarium* L.) occurs everywhere. (25) *Synedrella nodiflora* Gaertn., occurs in cultivated ground and waste places. (26) *Spilanthes acmella* Murr. occasionally found. (27) *Silybum marianum* Gaertn., occurs in gardens. (28) *Launaea asplenifolia* DC., and *L. pinnatifida* Cass. = *L. cermentora* Alston., very common weeds in grassy glades and open fields. (29) *Ethulia conyzoides* L., an erect annual herb. (30) *Erigeron asteroides* Roxb., another common weed. (31) Sagebrush (*Artemisia caruifolia* Ham.), a soft-stemmed plant, 2-4 ft. high. (32) *Echinops echinatus* Roxb., a branched annual, 1-2 ft. high, not

common. (33) *Chicorium intybus* L., an erect herb. (34) *Centrotherum anthelmenticum* O. Kuntze., a common tall robust annual. (35) *Sigesbeckia orientalis* L., a very common weed on the hills.

Affinity

Compositae has been regarded as the highest evolved family of dicotyledons by many taxonomists. Its similarity with the members of Rubiales, such as, Dipsaceae and Valerianaceae, is very remarkable. The notable features of similarity between Rubiaceae and Compositae are the aggregation of flowers into head or head-like structure and in the reduction of calyx-lobes. If the polyphyletic origin is taken into consideration, then it may be assumed that the origin of Rubiales and Compositae commenced from Umbelliferae,

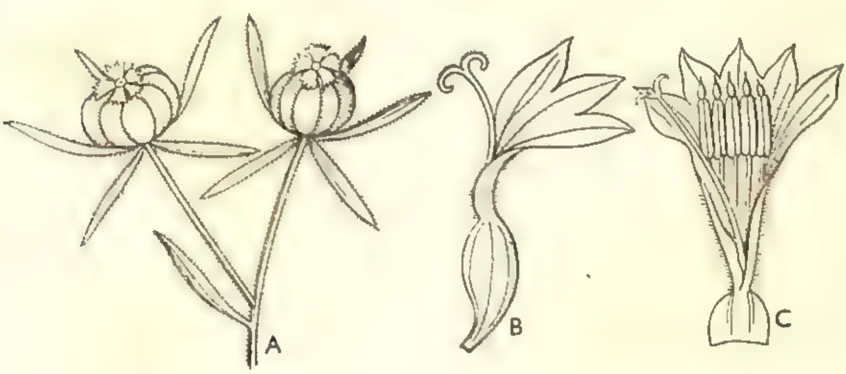


Fig. 684. Compositae (*Sigesbeckia orientalis*).
A, Portion of a flowering shoot; B, Ray floret; C, Disc floret partially split open.

which exhibits a tendency towards aggregation of small flowers in crowded umbels. Compositae, however, can be readily recognized by capitulum inflorescence with an involucre, presence of pappus, gamopetalous corolla (tubular or ligulate or both), syngenesious stamens, 1-celled inferior ovary with a single basal ovule, and cypsella fruit.

The reasons for treating Compositae as the highest evolved family are given below:

(1) The dominance of herbaceous habit.

(2) Presence of large number of species and their cosmopolitan distribution.

(3) The remarkable adaptation for cross-pollination by insects in the following:

(a) Easily accessible nectar and its protection from mechanical injury, such as, rain, cold, etc.

(b) Crowding of florets in capitula with ligulate marginal florets. These marginal florets usually act as flag for the attraction of insects.

(c) All the disc florets can be pollinated by a single insect within a very short time.

(4) The presence of syngenesious, protandrous stamens along with epigyny are considered as one of the advanced characters.

(5) The capacity of the florets to avoid self-pollination by brushing system (piston mechanism) along with the mechanism in the stigmas for the same purpose is undoubtedly the most advanced character of this family.

(6) The reduction of the calyx and the number of carpels, solitary ovule with inferior ovary, an the protection of tender florets are taken as the highly evolved characters of this family. The reduced calyx (pappus) serve as parachute mechanism for the distribution of fruits and seeds; this is also considered as one of the advanced characters.

Economic importance

This family is of economic importance to a great extent. Some plants are used as food for man, such as lettuce (*Lactuca*), artichoke (*Helianthus tuberosus*), endive (*Chicorium*), salisfy (*Tragopogon*), etc. A kind of orange dye is obtained from safflower (*Carthamus tinctorius*); the dried petals are adulterated with saffron. *Eupatorium*, *Wedelia*, *Vernonia* and *Sausseria lappa* are used in medicine. Oil is extracted from *Guizotia* and *Carthamus*. Several species of the genus *Artemisia* (*A. cina*, *A. vulgaris*, *A. maritima* var. *stechmaniana*) yield 'santonine' of medicine. Pyrethrum is obtained from *Chrysanthemum coccineum*. Some plants are ornamentals, such as Asters, *Chrysanthemum*, *Cosmos*, *Dahlia*, *Callandula*, *Gallardia*, Sunflower (*Helianthus*), *Tagetes*, *Zinnia*, *Senecio*, *Echinops*, etc.

GLOSSARY OF PLANT NAMES

The following abbreviations have been used :—

E. = English; *S.* = Sanskrit; *B.* = Bengali; *H.* = Hindi; *U.* = Urdu; *A.* = Assamese; *O.* = Oriya; *P.* = Punjabi; *G.* = Gujrati; *Bom.* = Bombay; *Mar.* = Marhati; *M.* = Malayalam; *T.* = Tamil; *Te.* = Telugu; *C.* = Canarese; *Sin.* = Sinhalee; *Bur.* = Burmese.

Abroma augusta L.

E. Devil's cotton; *B.* & *H.* Ulatkambal; *A.* Bon-kopashi; *O.* Pishachogonjai; *Bom.* Olatkambol; *T.* Sivaputhatti; *C.* Melpundigida.

Abrus precatorius L.

E. Indian liquorice, Crab's eye; *S.* Gunja; *B.* Kunch; *H.* Rati; *U.* Ghunchi; *A.* Latuwani; *O.* Roti; *P.* Ratak; *G.* Chanoti; *Bom.* Ghungchi, Gunja; *Mar.* Gunchi; *M.* Kunnikkura; *T.* Kunmani; *Te.* Guruginja; *C.* Galaganji, Guruganji; *Sin.* Olinda-wel; *Bur.* Ywegne.

Abutilon indicum G. Don.

E. Indian mallow; *S.* Kankatika; *B.* Potari; *H.* Kanghi; Jhampi; *U.* Kanghi; *O.* Nakochons; *P.* Simbol; *G.* Dabali; *Bom* Kangoi, Pamadni; *Mar.* Madmi; *M.* Tutti; *T.* Nallatutti, Tuthal; *Te.* Tutiribenda; *C.* Hettuti; *Sin.* Anode; *Bur.* Bonkhoe.

Acacia arabica Willd.

E. Babul, Gum tree; *S.* Babula; *B.* Babla; *H.* & *P.* Kikar, Babul; *U.* Babul; *A.* Torua-kadam; *O.* Boburi; *G.* Babulia, Baval; *Bom.* Babhula; *Mar.* Babhul; *M.* & *T.* Karuvelam; *Te.* Nallatumma; *C.* Jali; *Bur.* Naloakyine, Huanlongkyain.

Acacia catechu Willd.

E. Cutch tree; *S.* Khadira; *B.* Khayer; *H.* & *P.* Katha, Khair; *A.* Khoira; *O.* Khodiro; *C.* Kher, Kherio; *Bom.* Khaderi, Khaira; *Mar.* Khair; *M.* Kadaram; *T.* Kadiram; *Te.* Kasu, Sundra; C. Kungli; *Sin.* Ratkhiri; *Bur.* Sha.

Acalypha indica L.

S. Arithamunjariye; *B.* Muktajari; *H.* Kuppi, Khokli; *O.* Indramaris; *G.* Vanchhikanto; *Bom.* Khokli; *Mar.* Khajoti, Kupi; *M.* & *T.* Kuppamani; *Te.* Kuppintaku; *C.* Kuppi; *Sin.* Kuppamaniya.

Acanthus illicifolius L.

S. Harikusa; *B.* Hargoza; *H.* Harkuchkanta; *O.* Kilichiri; *Bom.* Nivagur; *Mar.* Marandi; *M.* Payinachhulli; *T.* Kaludaimulli; *Te.* Alchi; *C.* Holeculli; *Sin.* Ikiti; *Bur.* Khaya.

Achras sapota L.

E. Sapota, Sapodilla plum; *B.* Safeda; *H.* & *M.* Sapota; *O.* Sopato; *Bom.* Chikali; *T.* Simaiyiluppai; *Te.* Simaippa; *Bur.* Twottapat.

Achyranthes aspera L. = *Arva aspera* Spreng.

E. Prickly chaff-flower; *S.* Apamarga; *B.* Apang; *H.* Laljiri, Chirchiri; *A.* Ubtisath; *O.* Apomargo; *P.* Kutri; *G.* Aghedi; *Bom.* Aghada; *Mar.* Aghara; *M.* Katalati; *T.* Nayurivi; *Te.* Uttareni; *C.* Utranigida; *Sin.* Karalsebo; *Bur.* Kivalamon.

Aconitum napellus L.

E. Monk's hood; *S.* Kalkuta, Visha; *B.* Katbish; *H.* Mithazahar; *A.* Bish; *G.* Shangadio, Vachnag; *Mar.* Bachneg, Vashanav; *M.* Vatsanbhi; *T.* Vasanabhi; *Te.* Ativasa, Nabhi; *C.* Vasnabhi; *Sin.* Vachanabhi.

Acorus calamus L.

E. Sweet flag; *S.* Vacha; *B.* & *A.*

Bach; *H.* Gorbach; *U.* Bacha; *P.* Wach; *G.* Godavaj; *Mar.* Vekhand; *M.* Vashampa; *T.* Vasambu; *Te.* Vadaja, Basa; *C.* Baje; *Sin.* Wadakaha; *Bur.* Linhe.

Acronychia laurifolia Bl.=*A. pedunculata* Miq.

E. Clawflowered Laurel; *O.* Madhugodiyamado; *M.* Muttanari; *Te.* Muttainari; *C.* Bhutali; *Sin.* Ankenda.

Adansonia digitata L.

E. Baobab; *H.* Gorakamali; *G.* Bukha; *Bom.* Gorokchincha; *Mar.* Gorakhchinch; *T.* Anaippuli; *Te.* Brahmamlika; *C.* Brahmomlika.

Adenanthera pavonina L.

E. Red wood; *S.* Ranjaka; *B.* Ranjan; *H.* Barigumchi; *A.* Chandan; *O.* Sokakainjo; *G.* Badigumchi; *Mar.* Thorligunj; *M.* Manjati; *T.* Monjadi; *Te.* Gurivenda; *C.* Munjuti; *Sin.* Madateya; *Bur.* Ywegyi.

Adenostema viscosum DC.

B. Boro-keshurti.

Adhatoda vasica Nees.

E. Malabar nut; *S.* Atarusha, Vasika; *B.* Basak; *H.* Adalsa, Basak; *U.* Arusa; *A.* Bankaka; *O.* Bosongo; *G.* Adusa; *Bom.* Adulasa; *Mar.* Adulsi, Baksa; *M.* Attalokakam; *T.* Adadodi; *Te.* Atarushamu; *C.* Adsele; *Sin.* Agaladara; *Bur.* Ba-wa-net.

Adina coraïfolia Hook. f.

S. Dhara-kadamba; *B. & A.* Kelikadam; *H.* Haldu, Hardu; *O.* Kelikodombo, Holondo; *G.* Aldavan; *Mar.* Hedu; *M.* Katampa; *T.* Kadambai; *Te.* Kamba; *C.* Kadambe; *Sin.* Kolong; *Bur.* Hnaubeng.

Aegle marmelos Corr.

E. Wood apple, Bael tree; *S.* Sriphal, Bilva; *B. & A.* Bel; *H.* Bili, Sriphal; *U.* Bel; *O.* Belo, Bilwa; *G.* Billy; *Bom.* Bela; *Mar.* Bel; *M.* Vilvam; *T.* Villuvam; *Te.* Bilvamu, Sriphalamu; *C.* Bilva; *Sin.* Belli; *Bur.* Okshit.

Aerua lanata Juss.=*Arva lanata* Juss.

S. Astmabayda; *B.* Chaya; *H.* Kapurijadi; *P.* Buikallan; *G.* Kapurimadhuri; *Mar.* Kapurmadhura; *T.* Sirupulai; *Te.* Pindikumda; *Sin.* Polkudupala.

Aerua scandens Wall.=*Arva sanguinolenta* Bl.

B. Nuriya; *T.* Perumbulai; *Te.* Pindikonda.

Aeschynomene aspera L.

E. Indian cork-plant; *B.* Shola; *H.* Sola; *A.* Kunhila; *O.* Sholo; *M.* Bland; *T.* Takke; *Te.* Jiluga.

Aganosma caryophyllata G. Don=*A. dichotoma* K. Schum.

S. Sumana, Malati; *B. & H.* Malati; *O.* Maloti; *G. & Mar.* Malati; *M.* Cherupaval; *Te.* Palamalle; *C.* Malatilata.

Agave americana Roxb.

E. Century plant, American Aloe; *S.* Kantala; *B.* Bilati anarash; *H.* Kantala; *O.* Kolakantalo; *P.* Wiliyatikaitalu; *G.* Janglikunvera; *Bom.* Parkanda; *Mar.* Vilayatikorkand; *M.* Panankatta; *T.* Alagai, Anaikkattalai; *Te.* Kittanara; *C.* Anekatalle, Bhutale.

Ageratum conyzoides L.

B. Dochunty; *G.* Ajgandha; *Bom.* Osari; *Mar.* Ghaneraosadi; *M.* Appa; *Sin.* Hulantala.

Aglaia roxburghiana Miq.

S. Anganapriya, Gauro; *B. & H.* Priyangu; *O.* Priyongo; *M.* Punyeva, Sempuli; *T.* Kannikkombu; *Te.* Ettanduga; *C.* Tottila.

Albizzia lebbeck Benth.

E. Silk flower, Parrot tree; *S.* Kapitana, Shukapuspa; *B. & A.* Sirish; *H.* Garso, Seris; *U.* Darash; *O.* Siriso, Tinya; *G.* Kaloshirish; *Bom.* Harreri, Siris; *Mar.* Kalashiras, Shirish; *M.* Vaka; *T.* Siridam, Vagai; *Te.* Shirishamu, Dirisanamu; *C.* Bage, Sirisa; *Sin.* Mara; *Bur.* Kokko.

Allamanda cathartica L.

Bom. Jaharisontakka; *C.* Arasinhu.

Allium cepa L.

E. Onion; *S.* Palandu; *B.* Pianj; *H.* & *U.* Piyaz; *A.* Ponoru, Peyaz; *O.* Piaja; *P.* Peyaz; *G.* Dungari; *Bom.* Puyaj; *Mar.* Kanda; *M.* Bawang; *T.* Irulli; *Te.* & *C.* Nirulli; *Sin.* Lunu; *Bur.* Kesunni.

Allium sativum L.

E. Garlic; *S.* Lashuna; *B.* Rasun; *H.* Lasan; *U.* Lehsun; *A.* Naharu; *G.* Lasan; *Bom.* Lusoon; *Mar.* Lasun; *M.* Veluthulli; *T.* Vellaipundu; *Te.* Tellagadda; *C.* Belluli; *Sin.* Sudulunu; *Bur.* Kesumphiu.

Allophyllus cobbe Bl. = *A. serratus* Radlk.

B. Rakhalphul; *O.* Khondokoli; *Mar.* Tipani; *M.* Mukkanamperu; *T.* Amalai; *Te.* Eravalu, Juthika; *C.* Sisidale; *Bur.* Thankjot.

Alocasia indica Schott.

S. Manaka; *B.* & *A.* Mankachu; *H.* Mankanda; *O.* Manasaru; *P.* Arvi; *Mar.* Alu; *C.* Manaka.

Aloe indica Willd.

E. Indian Aloe; *S.* Adala; *B.* Ghritakumari; *H.* Ghiguvara; *U.* Ghiqwara; *O.* Ghritokumari; *P.* Ghikuar; *G.* Kuvara; *Mar.* Korkand; *M.* Kattala; *T.* Angani, Kattalai; *Te.* Kalabanda; *C.* Kattali.

Alpinia galanga Sw.

S. Kulanja; *B.* Kulinjan; *H.* Punnagchampa; Kulinjan; *U.* Kulanjan; *G.* Kolinjan; *Bom.* Bari-Kulanjan; *Mar.* Koshtkulinjan; *M.* pankijar; Aratta; *T.* Arattai; *Te.* Kacho-ramu; *C.* Rasmi; *Bur.* Padagoji.

Alstonia scholaris R. Br.

E. Devil's tree; *S.* Saptaparni; *B.* Chatim; *H.* Chatwan, Chatian; *A.* Chatian; *O.* Chhotina; *Mar.* Saptaparni, Satwin; *M.* Elilampala, Kotapala; *T.* Elilaippala, Palai; *Te.* Edakulapala; *C.* Hale, Madala; *Bur.* Lettop.

Alternanthera sessiles R. Br.

B. Chanchi; *O.* Madranga; *G.* Jalajambo; *Bom.* & *Mar.* Kanchari; *M.* Kozhuppa; *T.* Ponnanganni; *Te.* Pannaganti, Madanaganti; *C.* Honaganne; *Sin.* Mokunuwanna.

Amaranthus gangeticus L.

S. Marisha; *B.* Dengo, Lal-shak; *H.* Lalnatiya, Rajkiri; *U.* Lalsag; *G.* Adbondambho; *Bom.* Matichulai; *Mar.* Ranmat; *Sin.* Sudutampala.

Amaranthus spinosus L.

E. Prickly Amaranth, Foxtail; *S.* Tandula; *B.* Katanotey; *H.* Katalichaulai, Kantamiris; *A.* Katakhatura; *O.* Kanta; *P.* Chulai; *G.* Kantanudant, Tanjalja; *Mar.* Tandulja, Kantemat; *M.* Mullanchira; *T.* Mullukkirai; *Te.* Nalladoggali; *C.* Mulladantu; *Sin.* Katutampala; *Bur.* Hinnoesuba.

Amaranthus viridis L.

E. Amaranth; *S.* Tanduliya; *B.* Notey; *H.* Chaulai, Janglichurai; *G.* Dhimdo; *Mar.* Lhanamat; *T.* Kuppaikiral; *Te.* Mullatolakura; *Sin.* Kuratampala.

Ammania baccifera L.

E. Blistering Ammania; *S.* Kuranli; *B.* Dadmari; *H.* Kuranda; *U.* Agya; *P.* Dederbuti; *G.* Jalaagiyo; *Bom.* Agiya; *Mar.* Bharajambhula; *M.* Kallarvanchi; *T.* Kallarivi; *Te.* Agnivendapaku.

Amomum aromaticum Roxb.

E. Cardamum; *S.* Upakunchika; *B.* Elach; *H.* Elachi; *Mar.* Veldode.

Amoora cocculata Roxb.

B. Amurlatmi; *Bur.* Thitni.

Amoora rohituka W. & A. = *Aphanamixis polystachya* Blatter.

S. Rohitaka; *B.* Tiktaraj; *H.* Harinhara; *G.* Ragtarohido; *Mar.* Raktarohida; *M.* Sim; *T.* Vangul; Sem; *Te* Rohitaka; *C.* Mullumuttaga; *Sin.* Hingalgass; *Bur.* Chayankayou.

Amorphophallus campanulatus Bl.

E. Teliga potato; *S.* Arsaghna; *B. & A.* Ol-kachu, Ol; *H.* Zaminkand; *O.* Ola; *Bom.* Janglisuran; *Mar.* Suran; *M.* Karunakarang; *T.* Karunaikkalang; *Te.* Manchikanda; *Sin.* Kidaran; *Bur.* Wa.

Anacardium occidentale L.

E. Cashew nut; *S.* Kajutaka; *B.* Hijlibadam, Kaju; *H.* Kaju; *A.* Kajubadam; *O.* Hijilabodamo; *G. & Bom.* Kaju; *Mar.* Kajucha; *M.* Kashumavu; *T.* Mundiri, Sigidima; *Te.* Jidimamidi; *C.* Geru; *Sin.* Kaju; *Bur.* Thayet.

Andrographis paniculata Nees.

E. Creat; *S.* Bhuinimba, Kirata; *B.* Kalmegh; *H.* Kirayat; *A.* Kalpatita; *O.* Bhuinimbo; *G.* Kiryata; *Mar.* Olenkiroyat; *M.* Kiriyattu; *T.* Nelavembu; *Te.* Nelavema; *C.* Kreata; *Sin.* Ninbinkohomba.

Andropogon aciculatus Retz.

E. Love grass; *B.* Chorekanta, Nilaji; *H.* Bhatui, Chirchira; *A.* Bon-guti; *O.* Guguchio; *T.* Thutiri; *Te.* Gaddi; *Sin.* Tuttiri.

Andropogon sorghum Brot.=*Sorghum vulgare* Pers.

E. Indian Millet; *S.* Yavanala; *B.* Juar; *H.* Jowar; *A.* Joudhan; *O.* Bajra; *P.* Chotijuar; *G. & Bom.* Juar, Jowar; *Mar.* Juari; *M.* Chavela; *T.* Cholam; *Te.* Janu, Jonna; *C.* Jolah; *Sin.* Karaliringu; *Bur.* Pyoung.

Andropogon squarossus Cooke=*Vetiveria zizanioides* Stapf.

E. Khuskhus; *S.* Ushira; *B.* Khaskhas, Bena; *H.* Khas, Panni; *U.* Khas; *O.* Khas; *P.* Panni; *G.* Valo; *Bom.* Khasakkasa; *Mar.* Vata; *M. & T.* Vettiver; *Te.* Vattiveru; *C.* Lavancha; *Sin.* Saivandera; *Bur.* Miyamoe.

Aneilema nudiflora R. Br.

B. Kenduli; Kureli; *H.* Siyahmusli; *G.* Sismulia; *M.* Nelampulla; *C.* Nelacalu, Hullu.

Anisomeles ovata R.Br.=*A. indica* O. Kuntze.

B. Gobura; *O.* Bhuto-airi; *Bom.* Gopali; *M.* Poothachetayan; *T.* Peyamerutti; *Sin.* Yokwanasa.

Anogeissus latifolia Wall.

E. Button tree; *S.* Dhavala; *B.* Dhaoya; *H.* Bakli, Dhau; *U.* Bakla; *O.* Dhou; *C.* Dhavdo; *Bom.* Dhavada; *Mar.* Dhavda; *M.* Vellanava; *T.* Namai, Vekkali; *Te.* Vellama; *C.* Dinduga; *Sin.* Daawa.

Anona reticulata L.

E. Bullock's heart; *S.* Krishnabija; *B.* Nona; *H.* Ramphal; *A.* Atlas; *O.* Ramophalo; *G., Bom. & Mar.* Ramphal; *M.* Ramachchita; *T.* Ramachita; *Te.* Ramapandu; *C.* Ramaphala; *Sin.* Anoda; *Bur.* Awza.

Anona squamosa L.

E. Custard apple; *S.* Sitaphala; *B. & A.* Ata; *H.* Sarifa; *O.* Ato, Sitapholo; *G.* Anan; *Mar.* Sitaphal; *M.* Sirpa, Sitapalam; *T.* Atta, Sitapalam; *Te.* Sitapandu; *C.* Sitaphala; *Sin.* Atta; *Bur.* Auza.

Anthocephalus cadamba Miq.=*A. indicus* A. Reich.

S. Kadamba; *B. & H.* Kadam; *A.* Roghu; *O.* Kodombo; *G. & Bom.* Kadamba; *Mar.* Kadamba, Kadam; *M.* Katampa; *T.* Kadambu; *Te.* Kadambe; *C.* Bale; *Sin.* Kadamba; *Bur.* Ma-doo.

Antedesma ghaesembila Gaertn.

E. Black currant tree; *B.* Khudijam; *H.* Umtoa; *Mar.* Amati; *M.* Nulittali; *T.* Nolaidali; *Te.* Anepu; *C.* Nayikute; *Bur.* Kywepyisin.

Antigonon leptopus Hook. & Arn.

E. Virginian creeper; *B.* Ananta lata.

Antirrhinum majus L.

E. Snapdragon; *H.* Sanipat.

Aphania danura Radlk.

B. Danura.

Apium graveolens L.

E. Celery; *S.* Ajmoda; *B.* Chiluri; *H.* Ajmud, Bariajmud; *U.* Ajmod; *G.* Bodiajamoda; *Bom.* Ajmud; *Mar.* Ajmoda.

Arachis hypogaea L.

E. Ground nut, Pea nut; *B.* Chinebadam, *H. & P.* Mungphali; *G.* Bhuichana; *Bom.* Bhuiseng; *Mar.* Bhuimuga; *M.* Nelakkatala; *T.* Nilakkadalai, Verkkadalai; *Te.* Nilasanagalu, Verushanagalu; *C.* Kadale; *Sin.* Ratakaju; *Bur.* Myepe.

Areca catechu L.

E. Betel nut; *S.* Gubaka; *B.* Supari, Gua; *H.* Kasaili; *U.* Supari; *A.* Tambul; *O.* Gua; *G.* Sopari; *Mar.* Supari, Pung; *M.* Pugam, Pakka; *T.* Pakku; *Te.* Poka; *C.* Adike, Bette; *Sin.* Puwak; *Bur.* Kunse.

Argemone mexicana L.

E. Mexican poppy, Prickly poppy; *S.* Srigalkanta; *B.* Shialkanta; *H.* Katola, Pila katari; *A.* Kuhumkata; *O.* Kantakusham; *P.* Kandiari; *G.* Darudi; *Mar.* Firangidhotra; *M.* Brahmadanti; *T.* Brahmadandu; *Te.* Brahamadandi, Datturi; *C.* Datture; *Sin.* Balurakksia.

Arisaema speciosum Mart.

E. Snake plant; *H.* Sanpbuti; *P.* Samp-ki-khumb; *Sin.* Walkidaran.

Argyreia speciosa Sw.=*A. nervosa* Boj.

E. Elephant creeper; *S.* Hastiballi; *B.* Guguli; *H.* Samandarkapat; *U.* Samandarsotha; *O.* Monda; *G.* Samudrasosh; *Bom. & Mar.* Samudrashoka; *M.* Samudrapala; *T.* Samuthrappalai; *Te.* Samudrapachcha; *Sin.* Mahadumudu.

Artabotrys odoratissimus R. Br.=*A. uncinatus* Merr.

B. Kantali-champa; *H. & P.* Champa; *A.* Kothali champa; *O.* Chinichampa; *Bom.* Vilayatichampa; *M.* Manoranjitam; *T.* Manoranjidam; *Te.* Manoranjidamu; *C.* Manoranjanballi.

Artemisia caruifolia Ham.

E. Sage brush; *H.* Vilayti afsanten.

Artiplex hortensis L.

E. Salt brush.

Artocarpus incisa L.f.

E. Bread fruit; *T.* Erapillakai; *Sin.* Rata-del.

Artocarpus integrifolia L.=*A. heterophylla* Lamk.

E. Jack tree; *S.* Panasa; *B. & A.* Kantal; H. Kathar, Kattal; *U.* Katahal; *A.* Kotal; *O.* Ponoso; *P.* Katar; *G.* Vanas; *Bom. & Mar.* Phanas; *T.* Pila, Palasu; *Te.* Panasa; *C.* Halasu; *Sin.* Cos; *Bur.* Peinne.

Artocarpus lakoocha Roxb.

E. Monkey jack; *S.* Dahu; *B.* Dephal; *H.* Barhal, Lakuch; *A.* Chama, Dewa; *O.* Jento; *P.* Deheo; *G.* Lakucha; *Bom.* Lahu, Lovi; *Mar.* Votamba; *M.* Lakucham; *T.* Irappala; *Te.* Lakuchamu; *C.* Lakucha; *Sin.* Kaunagona; *Bur.* Mianktot.

Asclepias acida Roxb. = *Sarcostemma acidum* Voigt.

B. & H. Somelata; *Bom.* Soma; *Mar.* Ransher; *Te.* Tigatshumoodoo.

Asclepias curassavica L.

E. Milk weed, Silk weed; *P.* Kaktundi; *Bom.* Kuraki.

Asparagus racemosus Willd.

E. Asparagus; *S.* Shatavari; *B.* Satamuli; *H.* Satmuli, Satwar; *U.* Satavara; *A.* Hatmuli; *O.* Sotabori; *P.* Satwari; *G. & Bom.* Satavari; *Mar.* Satmuli; *M.* Satavali; *T.* Nirvittân, Sadaveri; *Te.* Satavari; *C.* Satamulike; *Sin.* Hatavari, *Bur.* Kanyomi.

Asphodelus tenuifolius Cav.

E. Asphodel; *H.* Bokat; *P.* Piyazi; *G.* Dungru.

Asystasia gangetica T. And.

T. Peyppatchotti; *Sin.* Puruk.

Atlantia monophylla DC.

S. Atavijambira; *O.* Narguni; *M.* Malanarakam; *T.* Perungurundu; *Te.* Adavinimma; *C.* Adavimimbi.

Atropa belladona L.

E. Deadly nightshade; *B.* Yebruj; *H.* Luckmuna; *P.* Suchi; *Bom.* Girbutita.

Avena sativa L.

E. Oat; *B.* Jai; *H.* Ganer. Jai; *P.* Ganerji; *C.* Togekoddi.

Averrhoa bilimbi L.

E. Bilimbi, Cucumber tree; *B.* Bilimbi; *H.* Belambu; *G.* Blimbu; *Mar.* Bilambi; *M.* Vilimbo; *T.* Pilimbi, Pulima; *Te.* Bilumbi, Bilibiti.

Averrhoa carambola L.

E. Carambola; *S.* Karmaranga; *B.* Kamranga; *H.* Khamrak, Karmal; *U.* Kamarakha; *A.* Kordai; *O.* Koromanga; *G.* & *Mar.* Kamarakha; *Bom.* Karamara; *M.* Kamarangam; *T.* Sagadam; *Te.* Karamonga, Tamarta; *C.* & *Sin.* Kamaranga; *Bur.* Zoun-ya-si.

Avicemnia officinalis L.

E. White Mangrove; *S.* Tuvama; *B.* & *H.* Bina, Tuvar; *G.* Tavariyan; *Mar.* Tiwar; *M.* Urppam; *T.* Kandal; *Te.* Madda; *C.* Upatti; *Bur.* Thamenet.

Bacaurea sapida Muell—Arg.

B. Latkan; *H.* Lutko; *A.* Letuku.

Bambusa arundinacea Willd.

E. Bamboo; *S.* Vansha, Kichaka; *B.* Bans; *H.* Bans, Kattang; *A.* Buah; *U.* Banse; *O.* Baunso; *P.* Magae; *G.* Wans; *Bom.* Dougi, Mandgay; *M.* Illi, Venu; *Mar.* Kallak; *T.* Mungil, Kambul; *Te.* Veduru; *C.* Bidaru; *Sin.* Kattuna; *Bur.* Kyakatwa.

Barleria cristata L.

S. Jhinti; *B.* Janti; *H.* Jhinte; *A.* Jhinli; *O.* Koilekha; *P.* Tadrelu; *T.* Udamulli; *Te.* Nirugoranta; *C.* Kuruvaka.

Barleria prionitis L.

S. Karuntaka; *B.* Kanta-janti; *H.* Katsareya; *O.* Dasokoronti; *G.* Kantashelio; *Bom.* Vajradanti; *Mar.* Kalsunda; *M.* Vetilakuttu. Chemmulli; *T.* Semmulli, Varalmulli; *Te.* Mundlagobbi; *C.* Kairantaka; *Sin.* Katakarardu; *Bur.* Leithaywa.

Basella rubra L.

E. Indian spinach; *S.* Putika; *B.* Pui-shak; *H.* & *O.* Poi; *U.* Poh; *A.* Purai; *G.* Pothi; *Bom.* Mayakbhaji, Velgond; *Mar* Mayalu; *M.* Basellakkira; *T.* Vaslakkirai; *Te.* Karubachchali; *C.* Kempabasale; *Sin.* Niviti.

Bassia latifolia Roxb.=*Madhuca latifolia* Macbride.

E. Mohwa tree, Butter tree; *S.* Madhuka; *B.* & *H* Mahua, Maul; *U.*Mahuava; *O.* Mahula; *G.* Mahuda; *Bom.* Moha; *Mar.* Maha; *M.* Irippa; *T.* Illupai; *Te.* Ippa.

Bauhinia acuminata L.

E. Mountain Ebony; *S.* Juggapatra; *B.* & *A.* Kanchan; *H.* Kachnar; *O.* Kanchona; *P.* Kairal.

Bauhinia purpurea L.

E. Mountain Ebony; *S.* Vanaraja; *B.* Devakanchan; *H.* Kaliar; *O.* Debkanjoro; *P.* Koralli; *Bom.* Atmatti; *Mar.* Debakanchana; *M.* Suvannamandaram; *T.* Mandarai; *Te.* Devakanjan; *C.* Utipe; *Sin.* Petan, Koblila; *Bur.* Mahahlegani.

Bauhinia variegata L.

E. Camel's foot tree; *S.* Raktakanchana; *B.* Raktokanchan; *H.* Kachnar, Khairwal; *U.* Kachnal; *O.* Borodo; *Bom.* Kanaraj, Kovidara; *Mar.* Raktakanchan; *M.* Kovidaram; *T.* Mandarai; *Te.* Mandara; *C.* Kanjivala; *Bur.* Bwechin.

Benincasa cerifera Savi. = *B. hispida* Cong.

E. Ash Gourd; *S.* Kushmanda; *B.* Chalkumra; *H.* Petha, Golkaddu; *U.* Petha; *O.* Panikharu; *G.* Koholu; *Bom.* & *Mar.* Kohala;

M. Kumpalam; *T.* Pushini; *Te.* Burdagumudu; *C.* Budekumbalakayi; *Sin.* Alupuhul; *Bur.* Kyaukpayon.

Beta vulgaris L.

E. Sugar Beet; *B.* Bitpalang; *H.* Chukandar, Polak; *U.* Chakundar; *A.* Beetpalang; *O.* Palongasago; *T.* Chakunda.

Biophytum sensitivum DC.

E. Sensitive Wood-sorrel; *S.* Jalapuspa; *B.* & *A.* Bonnarenga, Jhalai; *H.* Lakshana, Lajalu; *G.* Zarer; *Mar.* Ladjiri; *M.* Mukkutti, Thindanzni; *Sin.* Gas-nidikumba.

Bischofia javanica Bl.

E. West Indian cedar, Java cedar; *H.* Bhillar, Kain; *A.* Uriana; *O.* Dingiri; *Bom.* Bok; *M.* Nira, Tirippu; *T.* Tondi; *Te.* Nalupumushti; *Bur.* Yepadauk.

Blumea lacera DC.

S. Kukuradru; *B.* Barokukshima, Kukursunga, Shealmotra; *H.* Kukkurbanda, Kakrandi; *A.* Kukur-shuta; *O.* Kukursungha; *G.* Kokarunda; *Bom.* Nimurdi; *Mar.* Kukurbanda; *T.* Kattumulangi; *Te.* Karupogaku; *Bur.* Maiyagan.

Blyxa octandra L.

B. Seyala; *Sin.* Diya-hawariya.

Boehmaria nivea Hook. & Arn.

E. Rhea plant, Rami grass; *B.* & *H.* Kankhura; *A.* Rhea; *O.* Bryddhingi; *M.* Battischoriagenam.

Boerhaavia repens L.

E. Pigweed; *S.* Punarnava, Sathagni; *B.* Punarnaba; *H.* Thikri, Santh; *U.* Bashkira; *A.* Pononua; *O.* Punarnava; *G.* Vakhakaparo; *Bom.* Khapara, Punarnava; *Mar.* Kharaparya, Vasu; *M.* Thazuthama; *T.* Mukaratte; *Te.* Punarnava; *C.* Kommegida; *Sin.* Petasudupala.

Bombax malabaricum DC.=*Salmalia malabarica* Schott.

E. Red silk-cotton tree; *S.* Shalmali; *B.* Shimool; *H.* & *P.* Semab, Simbal; *A.* Simalu; *O.* Simuli; *G.* Shimlo; *Bom.* Semul, Shembal; *Mar.* Savane; *M.* Mullilavu, Pula; *T.* Elavam; Ilavu; *Te.* Buraga; *C.* Hatti, Kempuburaga; *Sin.* Kattu-imbul.

Bonnaya brachiata Link & Otto.= *Lindernia ciliata* Pennel.

B. Bhui-nim; *Sin.* Wila.

Borassus flabellifer L.

E. Palmyra palm; *S.* Taruraja, Tali; *B.* & *A.* Tal; *H.* Tar; *U.* Tad; *O.* Talo; *G.* Tad; *Mar.* Tad, Tamar; *M.* Talam; *T.* Talam, Panai; *Te.* Tadu; *C.* Tali, *Sin.* Tal; *Bur.* Tan.

Bougainvillea spectabilis L.

E. Glory of garden; *B.* Baganbilas.

Brassica campestris L.

E. Turnip; *B.* Shalgom; *H.* Chukandar.

Brassica juncea Hook. f. & Thom.

E. Mustard; *B.* Raisarisha; *H.* Rai.

Brassica napus L.

E. Rape; *S.* Sarsopa; *B.* Sarisha; *H.* & *P.* Sarson; *G.* Sarassava; *Bom.* Rai-sarson; *M.* Katuku; *T.* Kadugu; *Te.* Avelu; *C.* Sasiva.

Broussonetia papyrifera Vent.

E. Paper Mulberry.

Brownlowia lanceolata Benth.

B. Bolasundri, Kedarpundri.

Bruguiera gymnorhiza Lamk.

B. Kankra; *M.* Kantal; *T.* Ugappukakhandal; *Te.* Dudduponna.

Bryophyllum calycinum Salisb.

E. American life-plant; *S.* Parnabija; *B.* Patharkuchi, Koppata; *H.* Zakhmhaiyat; *U.* Chubehayat; *Bom.* Ahiravana; *T.* Malaikalli; *Te.* Simajamudu; *C.* Lonnahalakanagida.

Buchanania latifolia Roxb.=*B. lanzan* Spreng.

S. Piyalaka, Priyala; *B.* Piyal; *H.* Chironji, Piyar; *U.* Chironji; *O.* Priyalo; *P.* Chiroli; *Bom.* Charoli; *Mar.* Chirauli; *M.* Niruvi; *T.* Kattuma, Sarai; *Te.* Moralli, Sara; *C.* Charpoppu, Morale; *Bur.* Lambo.

Buettneria herbacea Roxb.

B. Kambraj.

Butea frondosa Roxb.=*B. monosperma* Taub.

E. Flame of the forest, Parrot tree; *S.* Palasha; *B. & A.* Palas; *H. & P.* Dhak; *U.* Palashpapra; *O.* Polaso; *G.* Khakara; *Bom.* Khakara, Palasa; *Mar.* Palash; *M.* Chamatha; *T.* Tikkuru, Palasu; *Te.* Moduga, Palasamu; *C.* Muttuga; *Sin.* Kalu-keale; *Bur.* Poukpex.

Butomus umbellatus L.

H. Briktshee.

Caesalpinia bonducella Flem.=*C. crista* L.

E. Fever nut; *S.* Kuberakshi; *B.* Nata; *H. & P.* Kathkaranj; *A.* Lataguti; *O.* Noto; *G.* Kakachia; *Bom.* Gaja, *Mar.* Gajaga; *M.* Kalanji; *T.* Gajji, Suriyindu; *Te.* Gacha; *C.* Gajjiga; *Sin.* Kumburuwel; *Bur.* Kaliendza.

Caesalpinia pulcherrima Sw.

E. Peacock flower; *S.* Krishnachuda; *B.* Krishnachura; *H.* Guletura; *A.* Swarnakanti; *O.* Krushnochuda; *M.* Techimandaram; *T.* Mayuram; *Te.* Sinnaturayi; *C.* Kenjige, Ratnagandhi; *Sin.* Monaramal; *Bur.* Ts-an-panpin, Daungsop.

Cajanus indicus Spreng.=*C. cajan* Mill.

E. Pigeon pea; *S.* Adhaki, Tuvarika; *B.* Arhar; *H.* Rahar; *A.* Raharmah; *O.* Horodo; *P.* Tohar, Dingeri; *G.* Turdal; *Bom.* Tura; *Mar.* Turi; *M.* Tuvara; *T.* Tuvarai; *Te.* Kandulu; *C.* Togari; *Sin.* Ratatora; *Bur.* Pai-si-song.

Calamus tenuis Roxb.

E. Cane palm; *S.* Vetasi; *B.* Bet.

Calamus rotang L.

E. Rattan; *S.* Vetra; *B.* Chanchibet; *M.* Purampu; *T.* Pirambu, Vettirom; *Te.* Bettamu; *C.* Betta; *Sin.* We-wel.

Callicarpa arborea Roxb.

B. Bormala, Kojo; *H.* Ghiwala; *A.* Khoja; *O.* Bornnopatri; *Bur.* Daungsatpya.

Callicarpa macrophylla Vahl.

B. Mathara; *H.* Daya; *M.* Chimpompil.

Calophyllum inophyllum L.

E. Alexandrian laurel; *S.* Nagachampa, Punnag; *B.* Punnag, Sultan champa; *H.* Surpan; *O.* Punnago; *Bom.* Undi; *Mar.* Nagchampa, Pumag; *M.* Punna; *T.* Punnai, Nagam; *Te.* Pouna; *C.* Honne; *Sin.* Dumba; *Bur.* Pengnyet.

Calotropis gigantea R. Br.

E. Madar, Swallow-wort; *S.* Arka; *B.* Akanda; *H.* Akond, Madar; *U.* Ak; *O.* Akondo; *G.* Akado; *Bom. & Mar.* Akra, Rui; *M.* Erikku; *T.* Arkkam; Erukku; *Te.* Arkamu; *C.* Arka, Ekke; *Sin.* Wara; *Bur.* Maioh.

Calotropis procera R. Br.

S. Alarka, Shveta; *B.* Shet-akanda; *H.* Safed-ak; *O.* Orko; *P.* Ak; *Mar.* Mandara; *T.* Vellerukku; *Te.* Jilledu; *Bur.* Mayopin.

Canavalia ensiformis DC. = *C. gladiata* DC.

E. Sword Bean; *S.* Mahashimbi; *B.* Makhan shim; *H.* Sema, Kadsambu; *A.* Katalurhi; *O.* Kolasimo; *P.* Sem; G. Gavria; *Bom.* Gaivara; *Mar.* Abai; *M.* Kanavala; *T.* Kolhiyavarai; *Te.* Ettammashimbi; *C.* Kadavare, Sambe; *Sin.* Walawara; *Bur.* Paikalag.

Canna indica L.

E. Indian shot; *S.* Sarvajaya; *B.* Sarbajaya, Kalabati; *H.* Kiawra;

A. Parijatphul; *O.* Sorbojoya; *P.* Hakik; *G.* Akalabera; *Mar.* Devakeli; *M.* Kattuvala; *T.* Puvalai, Kundimani; *Te.* Krishnatamara; *C.* Kalahu; *Sin.* Butsarana; *Bur.* Buddatharana.

Cannabis sativa L.
E. Hemp; *S.* Ganjika; *B.* Ganja; Bhang, Sidhi; *H.* Bhang, Charas; *O.* Bhango, Ganji; *P.* Bhangi; *G.* Bhang, Ganja; *Mar.* Bhang; *M.* Ginjilachilachi; *T.* Ganja, Bangi; *Te.* Ganjachettu, Bangiaku; *C.* Bhangi; *Sin.* Ganjagaha; *Bur.* Ben.

Canscora decussata Roem. & Schult.
S. Mahatikta, Sankhapuspi; *B.* Dankuni; *H.* Sankhahuli; *Mar.* Titavi; *M.* Cansjancora.

Canthium angustifolium Roxb.
E. Ceylon Box-wood; *B.* Kottamalli; *T.* Yorkoli, Nakkani; *Te.* Balasu; *C.* Hetteranike; *Sin.* Galkarinda.

Capparis horrida L.f.
B. Bagnai; *H.* Jhiri, Kalis.

Capparis sepiaria L.
S. Gridhranakhi; *B.* Bagashra, Kantagurkamai; *H.* Kanthari; *O.* Kontikopali; *P.* Hius; *G.* Kantharo; *Mar.* Kantharyel; *M.* Thoratti; *T.* Karindu; *Te.* Nallavuppi, Nalluppi; *C.* Kadukattari.

Capparis spinosa L.
E. Caper plant; *B.* Kabra; *H.* Kiari, Kobra; *U.* Kabar; *P.* Kabarra; *Bom.* Kabar; *Te.* Kokilakshmu; *C.* Mullukattari.

Capparis zeylanica L.
S. Kantakalata, Govindi; *B.* Keleykora, Asharcylata; *O.* & *Mar.* Govindi; *P.* Karvila; *T.* Kattotti, Tondai; *Te.* Doddi, Palaki; *C.* Totte, Tottulla.

Capsella bursa-pastoris Moench.
E. Shepherd's purse.

Capsicum frutescens L.
E. Chillie, Red Pepper; *S.* Marichiphala, Ujjvala; *B.* Lanka, Morich; *H.* & *P.* Lalmircha; *U.* Lalmarach; *A.* Jolokia; *O.* Lankamoricha; *G.* & *Mar.* Mirchi; *Bom.* Lalmirchi; *M.* Chabai, Ladamera; *T.* Mullagay; *Te.* Mirapakaiya; *C.* Menashinakayi; *Sin.* Gasmiris.

Carapa obovata Bl.
B. Dhundul; *O.* Susambar; *Bur.* Penglayoang.

Cardiospermum halicacabum L.
E. Baloon vine; *S.* Karnasphota, Jyotishmati; *B.* Lataphatki, Shibjhul; *H.* Kanphuti; *A.* Kapalphota; *O.* Latophitkiri; *P.* Lataphatkari; *G.* Garolio; *Bom.* Kanphuti; *Mar.* Kanphuti, Kapalaphodi; *M.* Joytishmati; *T.* Mudakottan; *Te.* Jyotishmatitige, Buddakakara; *C.* Erumballi; *Sin.* Penelvel; *Bur.* Malamai.

Carissa carandas L.
E. Currant; *S.* Karamandaka; *B.* Karamcha, Karja; *H.* Koronda, Karaunda; *U.* Karwanch; *A.* Korjatenga; *O.* Korondo, Khyirokoli; *G.* Karamarda; *Bom.* Karwand; *Mar.* Karavanda, Boronda; *M.* Karanta; *T.* Perungala; *Te.* Oka, Vaka; *C.* Heggarichige; *Sin.* Mahakaramba.

Carthamus tinctorius L.
E. Safflower; *S.* Kusumbha; *B.* & *A.* Kusumphul; *H.* Kussum; *O.* Kusumo; *P.* Karar; *G.* Kusumbo; *Bom.* Kusumba, Kardai; *Mar.* Kardai; *M.* Chendurakam; *T.* Sendurgam; *Te.* Agnisikha; *C.* Kusumbe.

Carum carui L.
E. Caraway; *S.* Krishnajiraka; *B.* Jira; *H.* Shiajira; *U.* Shahjirah; *P.* Zirasiyah; *G.* Shajiru; *Bom.* Vilayatizirah; *Mar.* Sahajire; *T.* Simaishembu; *Te.* Shimaisapu.

Carum copticum Benth. = *Trachyspermum amni* Spreng.
E. Ajowan; *S.* Yamanika, Yavani; *B.* Jowan; *H.* & *P* Ajwain; *A.* Joniguti; *O.* Juani; *G.* Ajamo; *Bom.* Ajwan, Owa; *Mar.* Owa; *M.* Ayamodakam; *T.* Omam; *Te.* Omamu; *C.* Oma Omu; *Sin.* Assamodum.

Carum roxburghiana Benth = *Trachyspermum roxburghianum* Craib.
B. Radhuni; *H.* Ajmot; *U.*

Karafas; *G.* Ajmod; *Mar.* Koranza, Ajmodavoma; *T.* Ashamtavomam; *Te.* Ajumodavoma.

Caryota urens L.
E. Indian Sago palm, Fishtail palm; *S.* Madadruma; *B.* Golsabu; *H.* Mari; *A.* Baraflawar; *O.* Solopo; *G.* Shankarjata; *Bom.* Birhimhad; *Mar.* Berli, Bherawa; *M.* Anappana; *T.* Tippilippanai, Irambanai; *Te.* Jivalaggu; *C.* Baini; *Sin.* Kittul; *Bur.* Minbo.

Cassia auriculata L.
H. Tarwar; *M.* Ponnaviram; *T.* Avari, Avaram; *Te.* Tangedu; *C.* Tangedi; *Sin.* Rana-wara.

Cassia fistula L.
E. Indian Laburnum; *S.* Suvarnaka; *B.* Shondal, Sonali, Bandar lathi; *H. & U.* Amaltas; *A.* Sonaru; *O.* Sunari; *P.* Alash; *G.* Garmula; *Mar.* Bahava, Boya; *M.* Konna; *T.* Irali, Konrai; *Te.* Rela, Kolaponna; *C.* Konde; *Sin.* Ehela; *Bur.* Gnoo-kye.

Cassia occidentalis L.
E. Western Senna; *S.* Kasamarda; *B.* Kalkashunda; *H.* Kasunda; *U.* Kasonji; *O.* Kasundri; *G.* Kasundari; *Bom.* Hikal; *Mar.* Kasoda; *M.* Karintakara; *T.* Peyavirai; *Te.* Kasinda; *C.* Kolutagase; *Sin.* Penitora; *Bur.* Maizali.

Cassia sophera L.
S. Talapota; *B.* Kalkashunda; *H.* Kasunda; *U.* Kalakasonji; *A.* Medelua; *O.* Kolokasunda; *G.* Kasundari; *Mar.* Kasodi; *M.* Pounantakara; *T.* Ponnavirai; *Te.* Tagara; *C.* Kasamarda; *Sin.* Urutora.

Cassia tora L.
E. Foetid Cassia; *S.* Chakramarda; *B. & H.* Chakunda; *O.* Chakundo; *P.* Pawar, Chakunda; *G.* Kovariya; *Bom.* Kowaria; *Mar.* Takala; *M.* Takara; *T.* Tagarai; *Te.* Tagirise; *C.* Chogache; *Sin.* Petitora; *Bur.* Dangywe.

Cassytha filiformis L.
S. Akashavalli; *B.* Akasbel; *H.* Amarbelli; *Bom.* Akaswel; *Mar.* Amarvela; *M.* Akashavalli; *T.* Indiravalli; *Te.* Nubutga; *C.* Akashaballi; *Bur.* Shwaynwaypin.

Casuarina equisetifolia Forst.
E. Beef wood, Whip tree; *B.* Jhau; *H.* Janglisaru; *O.* Jhabuko; *G.* Vilayatisaru; *Bom.* Sarokajhar; *Mar.* Sarpuhala; *M.* Suru, Chol; *T.* Savukku; *Te.* Chauku, Sarugudu; *C.* Chabaku; *Sin.* Kasa; *Bur.* Tinyu.

Cedrela toona Roxb.
E. Moulmein Cedar, Toon tree; *S.* Tooni, Nandivriksha; *B. & A.* Toon; *H.* Tun, Mahanim; *U.* Tun; *O.* Mahalimbo; *Bom.* Tuni, Tunna; *Mar.* Deodari; *M.* Tunnam; *T.* Tunu, Malivembu; *Te.* Nandi, Gati; *C.* Devadari, Garige; *Bur.* Tawtama.

Celosia argentea L.
E. White cock's comb; *S.* Vitunna; *B.* Sadamoragphul; *H.* Debkoti, Safaidmurga; *U. & P.* Sarwali; G. Lapadi; *Bom.* Khudu, Kurdu; *Mar.* Kurada; *T.* Pannai; *Te.* Guruga; *Sin.* Kirihenda.

Celosia cristata L.
E. Cock's comb; *S.* Mayurasikha; *B.* Moragphul; *H.* Lalmurga, Jatadhari; *U.* Asnana; *A.* Kukurajoaphul; *O.* Ganjachulia; *P.* Kanju, Malwal; *Mar.* Mayursikha; *M.* Kozhipullu; *Te.* Kodijuttutotakura; *Bur.* Kyetmonk.

Celsia coromandeliana Vahl. = *Verbascum coromandeliana*
S. Bhutakeshi; *B.* Kokshima; *H.* Gadartambaku; *O.* Kuntze; *G.* Kulahala; *Bom.* Kolhal; *Mar.* Kolhala, Kutki.

Centratherum anthelminticum O. Ktze.
S. Somraji; *B.* Babchi; Somraj; *H.* Bakshi, Somraj; *U.* Janglijiri; *O.* Somraj; *G. & Bom.* Kaligiri; *Mar.* Kalajira; *M.* Kalajirakam; *T.* Kattuchiragam; *Te.* Nelavavili; *C.* Kalajirige; *Sin.* Nironchi.

Cephalandra indica Naud. = *Coccinia indica* W. & A.
E. Scarlet gourd; *S.* Bimba, Tundika; *B.* Telakucha; *H.* Kundri, Bhimb; *U.* Kundaru; *A.*

Belipoka; *O.* Bimbo; *P.* Kundru; *G.* Ghobe; *Bom.* Bhimb, Tenduli; *Mar.* Bimbi, Tondali; *M.* Kova; *T.* Kovai; *Te.* Bimbika; *Sin.* Kovaka; *Bur.* Kenbung.

Ceriops roxburghiana Arn.
B. Goran; *M.* Ankantal; *T.* Pendikutti; *Te.* Gedera.

Cestrum nocturnum L.
E. Lady of the night, Mexican Jasmine; *B.* Hasnahena; *H.* Husnihena, Rat-ki-rani.

Chenopodium album L.
E. Goosefoot, Lamb's quaters; *B.* Bethoshak; *H.* Bethua; *A.* Jilmilshak; *O.* Bathusago; *P.* Bathu; *G.* Cheel, Tanko; *Bom.* Chakwit; *Mar.* Chakavata; *T.* Parupukkirai; *Te.* Pappukura; *C.* Chakravati.

Chenopodium ambrosides L.
E. Sweet Pigweed; *M.* Katuayamodakam; *C.* Kadavoma.

Chrozophora plicata A. Juss.
S. Suryavarta; *B.* Khudiokra; *H.* Sonaballi, Subali; *P.* Nilakrai; *G.* Okharada; *Te.* Guruguchettu.

Chrysanthemum coronarium L.
E. Chrysanthemum; *S.* Chandramallika; *B.* & *A.* Chandramallika; *H.* Guldaudi, Guldawri; *U.* Gulechini; *P.* Bagauri; *G.* Guldaudi; *Bom.* Seoti; *Mar.* Gulesevati; *T.* Shamantippu; *Te.* Chamanti; *Sin.* Lavulugas.

Cicer arietinum L.
E. Gram, Chick pea; *S.* Balabhojya; *B.* Chola; *H.* But, Chana; *A.* Bootmah; *O.* Bunta; *P.* Channa; *G.* & *Bom.* Chana; *Mar.* Harbara; *M.* Kadala; *T.* Kadalai; *Te.* Sanuagalu; *Sin.* Kondakadala; *Bur.* Kalapai.

Cichorium intybus L.
E. Chicory; *H.* Kasni; *U.* & *G.* Kasani; *P.* Gul; *T.* Kashini; *Te.* Kasini.

Cinnamomum camphora Nees.
E. Camphor; *S.* Karpura; *B.* Karpur; *O.* Kopuro; *M.* Himamsu; *T.* Karppuram; *Te.* Kappuramu; *Sin.* Kaparugala.

Cinnamomum tamala Nees.
E. Cinnamon leaf; *S.* Tejapatra; *B.* Tejpata; *H.* Tejpat; *O.* Tejapat; *Bom.* Tamala; *G.* Tamalpatra; *Mar.* Tamalapatra; *C.* Patraka; *T.* Talishapatturi; *Te.* Talisha; *Bur.* Thitchabo.

Cinnamomum zeylanica Breyn.
E. Cinnamon; *S.* Durusita; *B.* & *H.* Dalchini; *O.* Dalochini; *Mar.* Darachini; *M.* Erikkolam; *T.* Karruwas, Pulambilavu; *C.* Lavangapatta; *Te.* Sonalingu; *Sin.* Kurundu ; *Bur.* Hmanthin.

Citrullus colocynthes Schrad.
E. Colocynth, Bitter cucumber; *S.* Chitrala; *B.* & *H.* Indrayan; *U.* Indrayan; *A.* Koabhaturi; *P.* Tumma; *G.* Indranan; *Bom.* & *Mar.* Indrayan; *M.* Peykommutti; *Te.* Etipuchchha; *C.* Tumtikayi, *Sin.* Yakkomadu.

Citrullus vulgaris Schrad.
E. Water melon; *S.* Tarambuja; *B.* Tarmuj; *H.* & *P.* Tarbuza; *U.* Tarbuj; *A.* Kharmuja; *O.* Tarabhuja; *G.* Tarbuch; *Bom.* Kalinga, Turbuj; *Mar.* Kalingada, Tarbuj; *M.* Vattaka; *T.* Pitcha, Pullurhi; *Sin.* Penikomadu; *Bur.* Paye.

Citrus aurantium L. = *C. sinensis* Osbeck.
E. Orange; *S.* Naranga; *B.* Kamala; *H.* & *U.* Narangi; *A.* Kamalatenga; *O.* Narongo; *P.* Santara, Naringi; *G.* & *Bom.* Naringi; *Mar.* Naringa; *M.* Naranna; *T.* Narangam; *Te.* Narinja; *C.* Naranga, Kittile; *Sin.* Dodan; *Bur.* Thanbaya, Shonsi.

Citrus decumana L. = *C. maxima* Merr.
E. Shaddock, Pumelo; *S.* Madhukarkati; *B.* Batabinebu, Jambura; *H.* & *P.* Chakotra; *U.* Chokutrah ; *A.* Rebabtenga; *O.* Batabilembu; *G.* Obakotru; *Bom.* Papnas; *Mar.* Papnasa; *M.* Bambitinarakam; *T.* Pambalimasu; *Te.* Pampalamasam; *C.* Sakkota; *Sin.* Jambula; *Bur.* Shanktones.

Citrus medica L.
E. Lime, Lemon; *S.* Ruchaka,

Vijapura; *B.* Nebu; *H.* Limbu. Bijaura; *P.* Nimbu, Bijauri; *G.* Bijoru; *Bom.* Limu, Bijori; *Mar.* Limbu; *M.* Gilam, Matalanarakam; *K.* Kogilacham, Sidalai; *Te.* Lungamu; *Sin.* Sedaran; *Bur.* Shauktakera.

Clausena heptaphylla W. & A.
B. Karanphul; *H.* Ratanjot.

Clematis gouriana Roxb.
E. Traveller's joy, Virgin's bower; *B* Chagalbati; *H.* Belkangu; *O.* Boromojhanti; *Bom.* Moriel, Ranjai; *C.* Telejadari.

Cleome viscosa L. = *Polinasia viscosa* DC.
S. Arkakanta, Adityabhakta; *B.* Holdey hurhure; *H.* Kanphutia, Hulhul; *O.* Hurhura; *G.* Tilwan; *Bom.* Pivalatilavana; *Mar.* Kanphodi; *M.* Katkudagu; *T.* Naiveta, Nayikkadugu; *Te.* Kukhavovinta; *C.* Nayibela; *Sin.* Wal-aba.

Clerodendron inerme Gaertn.
S. Kundali, Vanajai; *B.* Bonjui, Batraj; *H.* Sangkupi; *U.* Cholora; *Bom. & Mar.* Vanajai; *M.* Nirnochi; *T.* Sanganguppi, Pinari; *Te.* Erupuchcha; *C.* Vishmadhar; *Sin.* Walguranola.

Clerodendron infortunatum Gaertn. = *C. viscosum* Vent.
S. Bhantaka; *B.* Ghetu; *H.* Bhant, Barangi; *O.* Bondari; *P.* Kalibasuti; *Bom. & Mar.* Bhandira, Kari; *M.* Peruku; *T.* Vellaikkanai; *Te.* Bogada, Guruja; *C.* Ittevu, Parele; *Sin.* Gaspinna; *Bur.* Bujiphyu.

Clerodendron siphonanthus R. Br.
S. Bhargi; *B.* Bamanhati; *H.* Barangi; *P.* Arni; *Bom.* Bharangi; *T.* Kavalai; *Te.* Bharangi, Brahmi; *Bur.* Naijamphati.

Clenogyne dichotoma Salisb.
B. Sithalpati.

Clitoria ternatea L.
E. Butterfly pea; *S.* Gokarnika; *B. & A.* Aparajita; *H.* Aparajit, Vishnukranti; *O.* Oporajita; *P.* Dhanattar; *G.* Garani; *Bom.* Kajali, Gokaran; *Mar.* Gokarni, Kajli; *M.* Sankapushpam, Aral; *T.* Kakkattan; *Te.* Dintena; *C.* Sankapuspaballi; *Sin.* Kattarodu; *Bur.* Bukiyu.

Cocos nucifera L.
E. Coconut; *S.* Narikela; *B.* Narikel; *H. & P.* Narial; *U.* Nariyel; *A.* Narikol; *O.* Gotoma; *G.* Nariel; *Bom.* Mar, Naril; *Mar.* Mad, Narel; *M.* Narikelam; *T.* Narigelam; Tennai; *Te.* Kobbera, Narikelamu; *C.* Kobari, Narikela; *Sin.* Polgaha; *Bur.* Ungbin.

Codiaeum variegatum L.
E. Garden Croton; *B.* Patabahar; *M.* Cera; *T. & Sin.* Croton.

Coffea arabica L.
E. Coffe plant; *B.* Kafi; *H.* Kahwa; *M.* Kappi, Bunnu; *T.* Kaddumallikal, Kapi; *Te. & C.* Kapi; *Sin.* Kopee

Coix lachryma-jobi L.
E. Job's tear; *S.* Gojivha; *B.* Kalokunch; *H.* Sankru; *A.* Koamonee; *O.* Garagada; *P.* Sanklu; *G.* Kasai; *Bom.* Kassaibija; *Mar.* Ranmakkai; *M.* Catri, Conda; *T.* Kattu, Kundumani; *Sin.* Karibu; *Bur.* Kycikphun.

Colchicum luteum Baker.
E. Autumn crocus, Meadow saffron; *S.* Hiranyatutha; *H.* Hirantutiya; *U.* Suranjanetalkh.

Coldenia procumbens L.
S. Tripakshi; *B. & H.* Tirupunkhi; *G.* Basriookharad; *Bom.* Tripakshi; *Mar.* Tripunkhi; *T.* Sirupadi; *Te.* Hamapadi.

Colebrookea oppositifolia Sm.
H. Binda, Bindu; *O.* Bosiki; *Bom.* Bahmani, Dasari; *P.* Basuti.

Coleus aromaticus Benth.
S. Pashanabhedi; *B.* Patharchur; *H.* Pathorchur; *Bom.* Owa, Pathorchur; *Mar.* Pathurchur.

Colocasia antiquorum Schott. = *C. esculenta* Schott.
E. Common Arum, Taro; *S.* Kachchi; *B. & A.* Kochu; *H.* Arvi, Kachalu; *O.* Saru; *P.* Alu, Kachalu; *Bom.* Kachualu, Terem;

Mar. Alu; *M.* Kaladi; *T.* Shamakkilangu; *Te.* Chamadumpa, Chema; *Sin.* Gahala; *Bur.* Mahuyapein.

Commelina benghalensis L.
E. Day flower; *S.* Kanchata; *B.* Kanshira, Dholapata; *H.* Kankauoa, Kanchara; *A.* Konasimolu; *O.* Korna; *P.* Kanna; *G.* Mhotunshushmutiyun; *Mar.* Kena, *T.* Kanangakarai; *Te.* Nirukassuvu; *C.* Hittagani.

Commelina obliqua Ham.
B. Jatakanshira; *H.* Kanjuna, Kana.

Convolvulus arvensis L.
E. Bindweed; *S.* Prosarani; *B.* Gandal; *H.* Beri, Harinpadi; *G.* Veladi; *Mar.* Chandvel; *T.* Hiranpaddi.

Corchorus capsularis L.
E. Jute; *S.* Kàlasaka; *B.* & *H.* Narcha; *Bom.* Chouchen; *Mar.* Chaunchan.

Corchorus olitorius L.
E. Jute; *S.* Nadika, Singgika; *B.* Pat; *H.* Koshta, Pata; *O.* Joto; *P.* Banphal; *Bom.* & *Mar.* Motichunch; *T.* Peratti; *Te.* Parinta.

Cordia myxa L.=*C. dichotoma* Forst. f.
E. Indian cherry; *S.* Bhutadruma; *B.* Bohari; *H.* Lasora, Bhairala; *U.* Lasora; *O.* Gondi; *G.* Gundomoto; *Bom.* & *Mar.* Bhokara, Bargund; *M.* Karati, Viri; *T.* Naruvili; *Te.* Nakkera, Virigi; *C.* Challe; *Sin.* Lotu; *Bur.* Thanat.

Cordia sebestena L.
E. Sebesten plum; *H.* Bhokar.

Coriandrum sativum L.
E. Coriander; *S.* Dhaniyaka; *B.* Dhoney; *H.* Dhaniya; *U.* Dhania; *G.* Konphir; *Bom.* Dhanya, Kothamira; *Mar.* Dhanya, Kothmir; *T.* Kotamalli; *Te.* Danyalu, Kotimiri; *C.* Havija, Kotambari; *Sin.* Kotthamallie; *Bur.* Naunau.

Corypha umbraculifera L.
E. Talipot Palm, Fan palm; *S.* Sritala, Tali; *B.* Tali; *Mar.* Bajarbattu, Tali; *M.* Talippana; *T.* Talipanai; *Te.* Sritalamu; *C.* Sritali, Baini; *Sin.* Tala; *Bur.* Pebin.

Costus speciosus Smith.
S. Kustha; *B.* & *H.* Keu, Kust; *O.* Khudo; *G.* Pokaramula; *Bom.* Kemuka; *Mar.* Pushkarmula, Pinnga; *M.* Anappu, Pushkaramulam; *T.* Kuttam; *Te.* Kushthamu; *C.* Chikke, Pushkaramula; *Sin.* Tebu; *Bur.* Patangtoungwae.

Crataeva religiosa Hook. f. & Th.
E. Caper tree; *S.* Ajapa; *B.* & *A.* Barun; *H.* & *U.* Barna; *O.* Boruno; *P.* Barna; *G.* Varno; *Bom.* Veyavarna, Kumla; *Mar.* Haravarna, Nirvala; *M.* Viravila, Kili; *T.* Narvala, Varanan; *Te.* Magalingam, Peddavulimidi; *C.* Mavilinga; *Sin.* Lunuwarana; *Bur.* Kadat.

Cressa cratica L.
S. Rudantika, Sanjivani; *H.* Lana; *U.* Rudanti; *Bom.* Khardi; *Mar.* Rudanti, Kharvi; *Te.* Uppusanaga.

Crescentia cujete L.
E. Calabash tree; *T.* Tiruvottukkay; *C.* Sokeburde.

Crinum asiaticum L.
S. Srikhanda, Vishari; *B.* Barokanur; *H.* Chindar, Kanwal; *U.* Nagadauna; *G.* Nagdamani; *Bom.* Nagdown; *Mar.* Nagadavana; *M.* Veluttapolatali; *T.* Vishamungil; *Te.* & *C.* Vishamungali; *Sin.* Tolabo ; *Bur.* Koyangi.

Crinum latifolium L.
S. Chakrangi, Vrishakarni; *B.* Sukhadarsan; *H.* Sukhdarsan; *Bom.* Gadambikanda; *T.* Vishamungil; *Sin.* Godamanil.

Crossandra undulaefolia Salisb.
M. Mannakhurinni; *Te.* Gobbi; *C.* Abboliga.

Crotalaria juncea L.
E. Sunn hemp; *S.* Shana; *B.* Shon; *H.* Shanahuli, Ghagahi; *A.* Ausa, Suila; *O.* Sono; *G.* San, Suna; *Bom.* Santag; *Mar.* Ghagharu, San; *M.*

Sanam, Chanaka; *T.* Chanai; *Te.* Janumu, Gilgichu; *C.* Sanabu; *Sin.* Hauna; *Bur.* Paikpiven.

Crotalaria retusa L.
E. Rattlewort; *S.* Shanarghandika; *B.* Atasi; *H.* Jhunjhunian; *A.* Ghantakarna; *O.* Junki; *G.* Ghughra; *Bom.* & *Mar.* Ghagri; *M.* Kutiri; *Te.* Pottigilligichcha; *Sin.* Kaha-andana-hiriya.

Croton tiglium L.
E. Croton-oil plant, Purging croton; *S.* Jayapala, Nepala; *B.* & *A.* Joypal; *H.* Jamalgota; *O.* Joyopalo; *G.* Nepal; *Bom.* Jaipa; *Mar.* Jepal, Jeyapal; *M.* Nirvalam; *T.* Nervalam; *Te.* Nepalamu; *C.* Japala, Nepala; *Sin.* Jayapala; *Bur.* Kanako.

Cryptocoryne ciliata Fisch.
B. Kerali; *T.* Nattativadayam; *Te.* Nattativasa.

Cryptolepis buchanamia Roem. & Schult.
H. Karanta; *O.* Gopikonirio; *M.* Kalipalvalli; *Te.* Gurugupalatege.

Cryptostegia grandiflora R. Br.
Mar. Vilayativakhandi; *M.* Pala; *T.* Palai.

Cucumis melo L.
E. Melon; *S.* Kharbuja; *B.* Kharmuj; *H.* Kakri, Kharbuza; *U.* Kharbuzah; *A.* Bangi; *O.* Kharbuja; *G.* Tarbucha; *Mar.* Chibunda; *M.* Thannimathai; *T.* Mulam, Vellarikai; *Te.* Peddakai; *C.* Kekkarikeballi, Ibbudtu.

Cucumis sativus L.
E. Cucumber; *S.* Trapusha, Sushitala; *B.* Sasha; *H.* Khira; *A.* Tiann; *O.* Kaknai; *Mar.* Kakdi; *M.* Mulluvellariak; *T.* Pipingha; *Te.* Dozakaya; *C.* Santekayi; *Sin.* Pipina; *Bur.* Tha-kwa.

Cucurbita maxima Duchesne.
E. Sweet gourd; *S.* Kushmanda; *B.* Mitha-kumra; *H.* Komara, Mitha-kaddu; *A.* Ronga-lau; *O.* Mitha-kokharu; *P.* Halwa-kaddu; *Bom.* Laldudiya; *M.* Mattanga; *T.* Pushini; *Te.* Gummadi; *C.* & *Sin.* Kumbala; *Bur.* Shwepayon.

Cucurbita pepo DC.
E. Pumpkin; *S.* Karkaru; *B.* Kumra; *H.* Safed kumra; *U.* Luki; *G.* Dudia; *Bom.* Kaula; *Mar.* Kohala; *Te.* Pottigummadi; *C.* Kumbala.

Cuminum cyminum L.
E. Point caraway; *S.* Jiraka; *B.* Jira; *H.* Safed zira; *U.* Jirah; *G.* Jiru; *Mar.* Jiregire; *M.* Jirakam; *T.* Shiragam; *Te.* Jiraka; *Sin.* Duru; *Bur.* Ziya.

Curculigo orchiodes Gaertn.
S. Musali; *B.* Talamuli; *H.* Mushali; *U.* Musali; *O.* Talomuli; *Bom.* Mushali; *Mar.* Kalimusali; *M.* Nelappanakizhanna; *T.* Nilapanni; *Te.* Nelatatigaddalu; *C.* Nelatatigadde; *Sin.* Heen-bin-tal.

Curcuma amada Roxb.
E. Mango ginger; *S.* Amragandha; *B.* & *A.* Amada; *H.* Amholdi; *U.* Ambahaladi; *O.* Ambakassia ada; *G.* Ambahaldara; *Bom.* Kajuragauri; *Mar.* Ambahaladi; *Te.* Mamidiallam; *C.* Ambaholdi.

Curcuma longa L.
E. Turmeric; *S.* Haridra; *B.* Halud; *H.* Holdi; *U.* Haladi; *A.* Halodhi; *G.* Halada; *Mar.* Halede; *M.* Manal; *T.* Manjal; *Te.* Pasupu; *C.* Arishina; *Sin.* Kaha; *Bur.* Hsanwen, Sanae.

Curcuma zedoaria Roscoe.
E. Indian Arrowroot; *S.* Kachura; *B.* Sathi, Ekangi; *H.* & *U.* Kachura; *G.* Kachuri; *Bom.* Kachura; *Mar.* Kachari; *M.* Kachcholam; *T.* Pulankilhangu; *Te.* Kachoram; *C.* Kachora; *Sin.* Harankaha; *Bur.* Thanuwen.

Cuscuta reflexa Roxb.
E. Dodder; *S.* Amaravela; *B.* Swarnalata, Alokelata; *H.* Amarabela, Akasbel; *U.* Imalbel; *A.* Akashilota, Amarlạti; *O.* Kolanirmuli; *P.* Nilathari; *G.* Amarabel; *Mar.* Amarvela; *T.* Kodiyagundal; *Te.* Lanjasavaramu; *Sin.* Agamulaneti-wel.

Cyanotis axillaris Schult. f.
H. Baganulla, Soltraj; *Bom.* Itsaka; *T.* Niriopalti; *Te.* Golagandhi.

Cycas circinalis Roxb.
E. Cycas; *B.* Biletikhejur; *M.* Toddamaram; *T.* Kama, Payindu; *Te.* Ranaguvva; *Sin.* Mahamadu.

Cynodon dactylon Pers.
E. Doob grass, Bermuda grass; *S.* Durva; *B.* Durba; *H.* Doob; *U.* Dub; *A.* Dubori; *O.* Dubaghasa; *P.* Dubra; *G.* Dhrokad; *Mar.* Durva, Karala; *T.* Arugampillu; *Te.* Gericha; *C.* Garikehulla.

Cynoglossum lanceolatum Forsk.
Sin. Bu-katu-henda.

Cyperus rotundus L.
E. Common Sedge; *S.* Mustaka, Gundra; *B.* & *H.* Mutha; *A.* Motha; *O.* Muthaghasa; *G.* Motha; *Bom.* Barikmoth; *Mar.* Bimbal; *M.* Kora; *T.* Korai; *Te.* Mustakamu; *C.* Tungegadde; *Sin.* Kalanduru.

Cyperus tegetum L.
E. Mat grass; *B.* Madurkati.

Daemia extensa R. Br. = *Pergularia daemia* Chois.
S. Uttarvaruni; *B.* Dudhilata; *H.* Sadowani, Utran; *O.* Uttururi; *G.* Amaradudheli; *Bom.* Utarni; *Mar.* Utarana; *M.* Veliparutti; *T.* Uttamani; *Te.* Guruti, Juttupaku; *C.* Belihatti.

Dalbergia latifolia Roxb.
E. Indian Rosewood; *S.* Shishapa; *B.* Sitsal; *H.* Vilayati shisham, Sitsal; *O.* Sissa; *P.* Shisham; *G.* Sisam; *Bom.* Shisar, Tivas; *Mar.* Shisu, Sisu; *M.* Karithi; *T.* Itti; *Te.* Jittegi; *C.* Todagatti.

Dalbergia sissoo Roxb.
E. Sisso; *S.* Aguru, Pichhila; *B.* Sisu; *H.* & *P.* Shisham; *O.* Sisu; *G.* Sissom; *Bom.* Sissu; *M.* Iruvil; *T.* Nukku, Pichai; *Te.* Sissu; *C.* Birade.

Datura fastuosa L. = *D. metel* L.
E. Black Datura; *S.* Krishnadhustura, Unmattavriksha; *B.* Kalodhutura; *H.* & *G.* Kaladhatura; *A.* Dhotura; *O.* Jambunodo; *Mar.* Kaladhotra; *M.* Ummata; *T.* Umattai; *Te.* Ummetta; *C.* Ummatta; *Sin.* Kaluattana; *Bur.* Pa-dain-game.

Datura stramonium L.
E. Thorn Apple; *S.* Dhutura, Unmattaka; *B.* Dhutura; *H.* & *U.* Dhatura; *O.* Dhutura; *P.* Dattura; *M.* Matulam, Ummata; *T.* Umattai; *Te.* Ummetta; *C.* Dattura, Ummatta.

Daucus carota L.
E. Carrot; *S.* Gajara; *B.* Gajar; *H.* & *U.* Gazar; *G.* & *Bom.* Gajar; *Mar.* Gazara; *T.* Gajjarakkilangu; *Te.* Gajjaragedda, Pitakanda; *C.* Gajjari.

Deeringia celosioides R. Br. = *D. amaranthoides* Merr.
B. Gholemouni; *H.* Latman.

Dendrocalamus strictus Nees
E. Solid Bamboo; *S.* Venu; *B.* Karail; *H.* Bans, Kopar; *O.* Sanobaunso; *G.* Nakorvans; *Mar.* Bans, Velu; *M.* Arinkantam, Karinkana; *T.* Karanai, Mungil; *Te.* Veduru; *C.* Kiribidiru; *Bur.* Myinwa.

Dentella repens Forst.
B. Bhuipat.

Derris scandens Benth.
E. Hog creeper; *B.* Noalata; *H.* Gonj; *O.* Kamocho; *P.* Gunj; *M.* Nulavalli; *T.* Anaikkatu, Tirani; *Te.* Chiratalabodi, Suruli; *Sin.* Kalawel; *Bur.* Mukyoungnway.

Desmodium gangeticum DC.
S. Shaliparni; *B.* Shalpani; *H.* Salpan; *U.* Shalwan; *O.* Salopornni; *P.* Shalpurhi; *G.* Salwan; *Bom.* & *Mar.* Salparni, Salwan; *M.* Pullati; *T.* Pulladi; *Te.* Gitanaram; *C.* Murelehonne.

Desmodium gyrans DC. = *D. motorium* Merr.
E. Telegraph plant; *B.* Gorachand, Boncharal; *H.* Banchal; *O.* Gorachondo; *Sin.* Chanchala.

Dianthus barbatum L.
E. Sweet William.

Dianthus caryophyllus L.
E. Carnation.

Dianthus chinensis L.
E. Pink.

Dicliptera roxburghiana Nees
P. Kirch, Semni.

Digera arvensis Forsk. = *D. muricata* (L.) Mart.
S. Manjarika; *B.* Latamouri; *H.* Latmahuria; *P.* Tartara; *G.* Kanajaro; *Bom.* Getan; *Mar.* Titana; *Te.* Chanchalikura.

Digitalis purpurea L.
E. Purple Foxglove.

Dipterocarpus turbinatus Gaertn. f.
E. Gurjan Balsam; *B.* Garjan; *A.* Kuralsal; *G.* Gurjun; *C.* Guge; *Sin.* Hora; *Bur.* Inbo.

Dischidia rafflesiana R. Br.
H. Bandikuri.

Dodonaea viscosa Jacq.
H. Aliar, Sonatta; *P.* Banmendu; *Bom.* Bandari; *Mar.* Luchmi; *M.* Virali; *T.* Verali; *Te.* Bandaru; *C.* Bandare; *Sin.* Etaverella.

Dolichandrone spathacea Schum.
M. Nirpoonalyam; *T.* Attukombudi, Kanabillai; *Sin.* Deyadanga; *Bur.* Thakutma.

Dolichos lablab L.
E. Dolichos, Black Bean; *S.* Shimbi; *B.* Shim; *H.* Sem; *A.* Uri, Urohi; *O.* Simba; *P.* Katjang; *G.* Oliya; *Bom.* Pauli, Valpapri; *Mar.* Anvare; *M.* Simapavaru; *T.* Avarai; *Te.* Annapa, Tellachikkudu; *C.* Avre; *Sin.* Irivija; *Bur.* Pai.

Dopatrium junceum Ham.
Bur. Bin-sawan.

Dracaena spicata Roxb.
H. Hiradukhi; *T.* Kandamiruga, Ratham; *Te.* Khadgarviru; *C.* Khadgarmurga, Netturu.

Dregea volubilis Benth. = *Marsdenia volubilis* Cooke
S. Hemavalli; *B.* Titakunga; *H.* Nakchhikni; *O.* Madhumaloti; *G.* Dodi; *Bom.* Dodhi; *Mar.* Ambri; *M.* Vattakkakkakkoti; *T.* Sivandi; *Te.* Palakura, Dudipala; *C.* Dugdhike; *Sin.* Kirianguna; *Bur.* Gwaytankpin.

Duabanga sonneratioides Ham.
B. Bandormulla.

Duranta plumieri Jacq.
B. Belatimehedi, Duranto; *H.* Nilkanta; *A.* Jeoragoch; *O.* Benjuati.

Dysophylla verticillata Benth.
B. Panikula; *Sin.* Hemanilla.

Ecbolium linneanum Kurz. = *E. viridis* Alston.
B. Nilkanta; *H.* Udajati; *O.* Nobhomondolo; *Mar.* Ranaboli; *M.* Kuranta; *T.* Nilambari; *Te.* Nakkatoka.

Echinops echinatus Roxb.
S. Utkantaka; *H.* Gokhru, Utakanta; *U.* Untkatara; *G.* Utkanto; *Mar.* Utanti, Utkantara.

Eclipta alba Hessk. = *E. prostrata* L.
S. Bhringaraja, Kesharaja; *B.* Kesuti; *H.* Babri, Bhangra; *U.* Bhangra; *A.* Kehoraji; *O.* Kesarda; *G.* Bhangra; *Mar.* Bangra, Maka; *M.* Kaiyanni; *T.* Kaikeshi; *Te.* Guntagalijeru, Galagara; *C.* Garaga; *Sin.* Kikirindi.

Ehretia acuminata R. Br. = *E. serrata* Roxb.
E. Heliotrope tree; *B.* Kulaja; *H.* Panyan, Chamror.

Eicchornia crassipes Solms.
E. Water Hyacinth; *B.* Kachuripana, Kachuri.

Elaeocarpus ganitrus Roxb. = *E. sphaericus* K. Schum.
E. Bead tree; *S.* Sivapriya, Rudraksha; *B.* Rudraksha; *H.* Rudrak; *O.* Rudrakhyo; *Mar.* Rudraksh; *M.* Rudraksham; *T.* Akkam; *Te.* Rudrachallu; *C.* Rudraksha.

Elephantopus scaber L.
E. Elephant's foot; *S.* Gojivha; *B.* Shyamdulum; *H.* Gobhi; *O.* Gobi; *Bom.* Hastipata; *Mar.* Gojibha; *T.* Anashovadi; *Te.* Hastikasaka; *Sin.* Et-adi; *Bur.* Katoopin.

Eleusine coracana Gaertn.
E. Ragi, African Millet; *S.* Rajika; *B.* Marua; *H.* Makra; *O.* Mandia; *P.* Mandal; *G.* Bavtonagli; *Bom.*

& Mar. Nagli; *M.* Panjappulla; *T.* Kelvaragu, Kayur; *Te.* Tamidelu; *C.* Ragi; *Sin.* Kurakkan.

Emilia sonchifolia DC.
B. Sadimodi; *H.* Sudhimude; *Bom.* Sadhimandhi; *M.* Mulshevi; *C.* Ihikivi ; *Sin.* Kadupara.

Enhydra fluctuans Lour.
E. Water Cress, Marsh herb; *S.* Hilamochika; *B.* Hingcha, Halencha; *H.* Harkuch; *A.* Helachishak; *O.* Hindimichi, Panisaga.

Entada scandens Benth. = *E. phaseoloides* Merr.
E. Mackay Bean; *B.* Gila; *H.* Garbi; *A.* Ghila; *O.* Giridi; *P.* Kastorikaman; *G.* Gardal, Pilpita; *Bom.* Garambi, Garbi; *Mar.* Garbe; *M.* Anatata; *T.* Irikki; *Te.* Gilatige; *C.* Hallekavi ; *Sin.* Pus-wel; *Bur.* Gonnyin.

Enterolobium saman Prain = *Samanea saman* Merr.
E. Raintree; *B.* Belatisirish; *O.* Bano sirisha; *M.* Urakkamthongimaram.

Eragrostis cynosuroides Beauv.
S. Kusha; *B.* Kush; *H.* Duv; *P.* Kusha; *Mar.* Darbha; *Te.* Kusha darbha, Durpa.

Eriobotrya japonica Lindl.
E. Loquat; *B.* Loket; *H.* Lokat; *U.* Lakhota; *T.* Ilakotta, Nakotta; *C.* Lakote.

Eriodendron anfructuosum DC. = *Ceiba pentandra* Gaertn.
E. White Cotton tree; *B.* Shetsimul; *H.* Kapok, Hattian; *U.* Sambal; *Mar.* Pandhari, Shamicula; *M.* Illavi, Pula; *T.* Ilavam, Illaku; *Te.* Burga; *C.* Apurani, Biliburaga; *Sin.* Imbul; *Bur.* Thinbawle.

Erythrina indica Lamk. = *E. variegata* L.
E. Coral tree; *S.* Parijata, Mandara; *B.* Palitamadar; *H.* Pangra; *A.* Mondar; *O.* Mondaro; *G.* Panarawes; *Mar.* Pangara; *M.* Kulumurikku; *T.* Kaliyanamurukku; *Te.* Baridamu, Baditachettu; *C.* Halivana, Hongara; *Sin.* Erabadu ; *Bur.* Pinle-kattit.

Eucalyptus globulus Labill.
E. Eucalyptus tree; *T.* Karpuram; *Te.* Karpuramu; *C.* Karpura.

Eugenia caryophyllaea Wight. = *Syzium caryophylla* Alston
E. Clove; *B.* Lavanga; *H. & A.* Laung; *O.* Labanga; *M.* Grampu.

Eugenia jambolana Lamk. = *Syzium cumini* Skeels.
E. Jambu, Black plum; *S.* Jambu; *B.* Kalojam; *H. & P.* Jamun; *U.* Jaman, Phalenda; *A.* Jamu; *O.* Kalajamo; *G. & Bom.* Jambu; *Mar.* Jam, Jaman; *M.* Naga, Naval; *T.* Arugadam, Naval; *Te.* Jambuvu, Neredu; *C.* Neralu; *Sin.* Mahadan; *Bur.* Thabyebyu.

Eugenia jambos L. = *Syzium jambos* Alston
E. Roseapple; *S.* Jambu; *B.* Golapjam; *H. & Bom.* Gulab jamun; *U.* Gulabjaman; *A.* Golabjamu; *T.* Perunaval; *Te.* Peddaneredu; *M.* Jambu; *C.* Jamba; *Sin.* Jambu.

Eugenia melaccensis L. = *Syzium malacense* Merr. & Perry.
E. Malay Apple; *B.* Jamrool; *H.* Malayajam.

Eupatorium ayapana Vent.
B. & H. Ayapan; *G.* Alleppa; *Mar.* Ayapana; *T. & Te.* Ayapani.

Euphorbia antiquorum L.
E. Cactus; *S.* Vajrakantaka; *B.* Tesiramonsa, Bajbaran; *H.* Tridharasechund; *U.* Zakum; *O.* Dokanasiju; *G.* Tandharisend; *Mar.* Naraseja; *M.* Katakkalli; *T.* Sadurakalli, Kalli; *Te.* Bontajemudu; *C.* Bontekalli; *Sim.* Daluk; *Bur.* Pyathal.

Euphorbia microphylla Heyne
B. Chotokarni; *G. & Mar.* Dudhi.

Euphorbia nerifolia L.
S. Snuhi; *B.* Monsasij, Monsa; *H.* Sij, Sehund; *A.* Siju; *O.* Patarasiju; *P.* Gangichu; *G.* Thor; *Bom.* Minguta, Thor; *Mar.* Nevagunda;

M. Illakali; *T.* Illaikkalli; *Te.* Akujemudu; *C.* Yalekalli; *Bur.* Shasoung.

Euphorbia pilulifera L. = *E. hirta* L.
S. Pushitoa; *B.* Barokarni; *H.* Dudhia; *Bom.* Nayetti; *Mar.* Dudnali; *M.* Nelapalai; *T.* Pallavi; *Te.* Nanabala; *Sin.* Bu-dada-kiriya.

Euphorbia pulcherrima Willd. = *Poincettia pulcherrima* R. Grah.
E. Poincettia; *B.* Lalpata; *A.* Lalpat; *O.* Lalpatra; *T.* Mayilkanni.

Euphorbia thymifolia Burm.
S. Laghudugdhika; *B.* Shetkorni; *H.* Chhotidudhi; *P.* Baradodak; *G.* Nahanidudheli; *Bom.* Nayata; *Mar.* Lahandudhi; *T.* Sittrapaladi; *Te.* Reddivarimanubala; *Sin.* Bindadakuriya.

Euphorbia tirucalli L.
E. Milk hedge; *S.* Trikuntaka; *B.* Lankasij; *H.* Sehund, Konpal; *U.* Zakum; *O.* Lonkasiju; *G.* Dandaliothora; *Bom.* Thora; *Mar.* Nevli; *M.* Kolkalli; *T.* Tirukkalli, Kombukalli; *Te.* Chemudu; *C.* Kodukalli; *Sin.* Navahandi; *Bur.* Shashoungleknyo.

Euryale ferox Salisb.
E. Foxnut; *S.* Kakhana; *B.* Makhna, Kantapadma; *H.* & *U.* Makhana; *A.* Nikori; *O.* Kuntapadma; *P.* Jewar; *Te.* Mellunipadmanu.

Evolvulus alsinoides Wall.
S. Vishnukranta; *H.* Shyamakranta; *O.* Bichamalia; *G.* Kalisankhavli; *Bom.* Shankhavalli; *Mar.* Vishnukanta; *M.* & *T.* Vishnukranthi; *Te.* & *Sin.* Vishnakranta.

Evolvulus nummularius L.
B. Bhuiankra.

Exacum tetragonum Roxb.
B. Kuchuri; *H.* Titakhana.

Excoecaria agallocha L.
E. Blinding tree, River poison; *S.* Agaru; *B.* Geo; *H.* Gwa; *O.* Ghona; *Bom.* Geva; *Mar.* Surund; *M.* Katappala; *T.* Agadil, Tillai; *Te.* Chilla, Tellachettu; *Sin.* Telakiniya; *Bur.* Kayan.

Feronia elephantum Corr. = *F. limonia* Swingle
E. Elephant Apple; *S.* Kavittha; *B.* & *A.* Kaithbel; *H.* Kaithbel, Kaitha; *U.* Kaitha; *O.* Koitho; *P.* Kait; *G.* Kotho; *Bom.* Kavit; *Mar.* Kauth; *M.* Manmatham; *T.* Kavithamu, Karuvila; *Te.* Velaga; *Sin.* Diwul; *Bur.* Thibin.

Ferula asafoetida Boiss.
E. Asafoetida; *S.* Hingu; *B.* & *H.* Hing; *U.* Anjadana; *O.* Hingu; *G.* Hing; *Bom.* Hingra; *M.* Kayam; *T.* Perungayam; *Te.* Inguva.

Ficus benghalensis L.
E. Banyan tree; *S.* Vitapi, Vata; *B.* Bot; *H.* & *P.* Bargad; *U.* Bargoda; *A.* Borgach; *O.* Boto; *G.* Vad; *Mar.* Vada, War; *M.* Vatam; *T.* Vadam, Ala; *Te.* Vitapi; *C.* Ala, Vata; *Sin.* Mahanuga; *Bur.* Pyinyoung.

Ficus cunea Ham.
E. Fig; *S.* Kharapatra; *B.* Dumur; *H.* Khenan; *O.* Godima; *Mar.* Porodumer; *M.* Perina; *T.* Taragadi; *Te.* Bommamatti; *Bur.* Thadut.

Ficus glomerata Roxb.
E. Fig; *S.* Udumbara; *B.* Jagyadumur; *H.* & *U.* Gular; *A.* Dimoree; *O.* Dimiri; *P.* Anjir, Kathgular; *G.* Umar; *Bom.* Umbar; *Mar.* Atti, Umbara; *M.* Andumbaram; *T.* Anjiram; *Te.* Bodda; *C.* Rumadi; *Sin.* Atteeka; *Bur.* Thapan.

Ficus hispida L. f.
S. Kakodumbarika; *B.* Kakdumur; *H.* Kagsha, Gobla; *O.* Bhaidimiri; *P.* Daduri, Degar; *G.* Jangliangir; *Bom.* Dumbar; *Mar.* Bhokada, Kharoti; *M.* Peyatti; *T.* Ottannalam; *Te.* Kukkabodda; *C.* Kadatti; *Sin.* Kotadimbula; *Bur.* Kadot.

Ficus infectoria Roxb.
S. Parkati; *B.* Pakur; *H.* Pakar; *U.* Pakharia; *O.* Pakodo; *P.*

Pakhar; *G.* Pepri; *Bom.* Pakri; *Mar.* Pakari; *M.* Bakri; *T.* Jovi. Kallal; *Te.* Jovvi; *C.* Basari; *Sin.* Kiripella; *Bur.* Nyoungchin.

Ficus religiosa L.
E. Peepul tree, Bo-tree; *S.* Asvatha. Bodhidruma; *B.* Asathwa; *H.* & *U.* Pipal; *A.* Anthot; *O.* Oshwotho; *P.* Pipal, Bhor; *G.* Pipul; *Bom.* Pipal, Jari; *Mar.* Asvatha, Pimpala; *M.* Asvatham, Araval; *T.* Arasu, Asuvattam; *Te.* Asvatthamu, Ravi; *C.* Aswatha, Aralimara; *Sin.* Bo-gaha; *Bur.* Nyoungbaude.

Fimbristylis junciformis Kunth
B. Bindimuthi.

Finlaysonia obovata Wall. = *F. maritima* Backer
B. Dudhilata.

Fleurya interrupta Gaud.
E. Nettle; *B.* Lalbichuti; *H.* Surat; *A.* Sharuchorat, Sirnat; *O.* Bichati; *M.* Anachoriyanam; *T.* Ottapilavu, Ottarbata; *Sin.* Mausa; *Bur.* Pheytakyee.

Foeniculum vulgare Gaertn.
E. Fennel, Anise; *S.* Madhurika; *B.* Mouri; *H.* & *P.* Saunf; *U.* Sonf; *A.* Guamoori; *O.* Panmohuri; *G.* Variari; *Bom.* Barishopa; *Mar.* Badisep; *T.* Sohikirai; *Te.* Peddajilakaramu; *C.* Badisopu.

Fragaria nilgherrensis Schldl.
E. Strawberry.

Gangrea maderaspatana Poir.
B. Namuti; *H.* Mustaru; *U.* Afsantin; *G.* Jhinkimundi; *Mar.* & *T.* Mashipatri; *M.* Nelampala; *Te.* Save; *C.* Dovana; *Sin.* Velkolondu.

Garcinia cowa Roxb.
E. Cowa tree; *B.* Kaglichu, Kau; *H.* Cowa; *Bur.* Madow.

Garcinia mangostana L.
E. Mangosteen; *B.* & *H.* Mangustan; *O.* Sulambuli; *Mar.* Mangastin; *M.* Manggusta; *T.* Sulambuli; *Sin.* Mangus; *Bur.* Mengkop.

Gardenia florida L. = *G. jasminoides* Ellis.
E. Cape Jasmine; *S.* Gandharaja; *B.* Gandharaj; *H.* Papra, Dikmali; *A.* Togor; *O.* Gondhorajo; *T.* Kambil; *Te.* & *C.* Adavibkki; *Sin.* Galis.

Gelonium multiflorum A. Juss.
B. Bonnaranga; *H.* Bannaringa; *Te.* Karujuggilam.

Geranium nepalense Sw.
E. Crane's Bill; *H.* & *P.* Bhand, Bhanda.

Geranium ocellatum Camb.
H. Bhanda.

Globba bulbifera Roxb.
B. Kandhapuspa; *Te.* Kondapasupu.

Gloriosa superba L.
E. Glory Lily; *S.* Agnisikha, Langulika; *B.* & *A.* Ulatchandal, Bisalanguli; *H.* Kalihari; *U.* Kulhar; *O.* Ognisikhha; *P.* Kariari; *G.* Dudhiovachhnag; *Bom.* & *Mar.* Karianag; *M.* Mettonni, Kantal; *T.* Kandal, Tondri; *Te.* Agnishikha; *C.* Agnisikhe; *Sin.* Niyangalla; *Bur.* Hseemee-touk.

Glycerrhiza glabra L.
E. Liquorice; *S.* Madhuka; *B.* Jastimodhu; *H.* Jethimadh, Mulhatti; *P.* Muleti; *G.* Jethimadha; *Bom.* Jashtimadhu; *Mar.* Jesthamadha; *M.* Yashtimadhukam; *T.* & *Sin.* Atimaduram; *Te.* Atimadhuramu; *C.* Yasthimadhuka; *Bur.* Noekhiyu.

Glycosmis pentaphylla Corr.
E. Toothbrush plant; *S.* Ashvashakota; *B.* Ashshaora; *H.* Bannimbu; *A.* Chauldhoa; *O.* Chanoladhua; *Bom.* Kirmira; *M.* Panal; *T.* Kattukkonji, Anam; *Te.* Golugu; *C.* Guruvede; *Sin.* Dodampana; *Bur.* Obok, Tanshouk.

Gmelina arborea Roxb.
E. White Teak; *S.* Gambhar; *B.* Gamari; *H.* Gamhar, Sewan; *A.* Gomari; *O.* Gombhari; *G.* Savan; *Bom.* Kashmari, Shewun; *Mar.* Gamar, Shiwan; *M.* Kumbili; *T.*

Kumil, Kumbali; *Te.* Gumudu. Kashmari; *C.* Kashmiri, Kumule; *Sin.* Atdemmata; *Bur.* Ya-ma-nai.

Gnetum scandens Roxb.
O. Lolori; *Bom.* Kumbal, Umbli; *M.* Ula; *C.* Kodkamballi; *Bur.* Gyutnwa.

Gomphrena globosa L.
E. Globe Amaranth, Bachelor's Buttonhole; *B.* Gulmakmal; *H.* Gul-i-makhmal.

Gossypium herbaceum L.
E. Cotton plant; *S.* Karpasi; *B.* Kapas, Tula; *H.* Kapas; *A.* Kopah; *O.* Kopa; *P.* Rui; *G.* Ru; *Bom.* Rui, Kapas; *M.* Karppasi, Paritti; *T.* Panji, Parutti; *Te.* Patti; *C.* Hatti, Arabi; *Bur.* Wah.

Gouania leptostachya DC.
U. Khanta; *C.* Shingarballi; *Bur.* Thayawnyonway.

Grewia asiatica L. = *G. subinaequalis* DC.
S. Purusha; *B.* Phalsa; *H.* Sukri; *U.* Phalasah; *O.* Pharosaholi; *P.* Phalsah, Pharnu; *G.* Phalsa; *Bom.* Phalasi; *Mar.* Phalsi; *M.* Chadicha; *T.* Tadachi; *Te.* Phutiki; *C.* Tadasala; *Sin.* Dowaniya.

Guazuma tomentosa Kunth.
E. Bastard cedar; *B.* Nepaltunth; *O.* Debodaru; *M.* Rudraksham; *T.* Tengai, Tenbachai; *Te.* Udrikpatta; *C.* Rudrakshi, Bucha.

Guizotia abyssinica Cass.
E. Niger seed; *B.* Sarguja; *H.* Surguja, Kalatil; *G.* Kalatel; *Bom.* Kerani, Ramatila; *Mar.* Kalitil; *Te.* Valesulu, Vulisi.

Gynandropsis pentaphylla DC. = *G. gynandra* Briq.
E. Spider flower; *S.* Surjyavarta, Arkapuspika; *B.* Sada hurhure; *H.* Charota, Safaid hurhur; *A.* Bhutmula; *O.* Anasorisia; *G.* Tanmani; *Bom.* Mabli; *Mar.* Tilavana; *M.* Karavela, Taivela; *T.* Naikadugu, Velai; *Te.* Vaminto; *Sin.* We-la.

Gyrocarpus americana Jacq.
B. Zaitan.

Hamiltonia suaveolens Roxb.
P. Kantalu, Pudari; *Bom.* Didesa, Gidasawa.

Hardwickia pinnata Roxb.
B. Anjan; *Mar.* Anjana; *M.* Kiyavu; *T.* Acha; *Te.* Yepi; *C.* Enne.

Hedychium coronarium Koenig
B. Dulalchampa.

Helianthus annuus L.
E. Sunflower; *S.* Adityabhakta; *B.* Surjamukhi; *H.* & *P.* Surajmukhi; *U.* Surajamakkhi; *A.* Beliphul; *Bom.* Surajmaki; *Mar.* Surajmaka; *T.* Suriyakanti; *Te.* Suriyakanta; *C.* Hottutirugana; *Sin.* Siriyakanthiya.

Helianthus tuberosus L.
E. Artichoke; *B.* Hatichoke; *H.* Atipich, Hathichak.

Helicteres isora L.
S. Mrigasingha; *B.* Antmora; *H.* Bhendu, Marosi; *U.* Marophali; *O.* Orola; *P.* Marorphali; *G.* Murdasing; *Bom.* Kawun; *Mar.* Kewan, Muradsing; *M.* Valampiri; *T.* Valambui; *Te.* Gubalada, Kavanchi; *C.* Edamuri, Murudi; *Sin.* Zimiagaha; *Bur.* Thungeche.

Heliotropium indicum L.
E. Heliotrope; *S.* Hatisunada; *B.* & *O.* Hatisura; *H.* Hattasura; *A.* Hatisur; *G.* Hathisundhana; *Bom.* Burundi; *Mar.* Bhurundi; *M.* Teliyanni, Telkotukka; *T.* Telkodduki; *Te.* Telumani; *Sin.* Dimibiya.

Heliotropium ovalifolium Forsk.
B. Nagaphuli; *Te.* Nagadanti.

Hemerocallis fulva L.
B. Gulnargis.

Hemidesmus indicus R. Br.
E. Indian Sarsaparilla; *S.* Anantamula, Sugandhi; *B.* & *A.* Anantamul; *H.* Salsa; *O.* Sugondhi; *G.* & *Mar.* Upalasari; *Bom.* Upasara; *M.* Narunari; *T.* Nannari; *Te.* & *C.* Sugandhipala; *Sin.* Irimusu.

Heritiera minor Roxb.
E. Looking-glass tree; *B.* Sundri;

H. Sundari; M. Mukuram; T. Chemuntiri, Conmundiri; Te. Adavibademu; Sin. Etuna.

Herpestis monnieria H. B. & K.
S. Brahmacharini; B. Brahmi; H. Barambhi, Safed chamni; U. Jalanim; O. Krishnaparni; Bom. Bama; T. Brame, Hirbrami; Te. Sambranichattu; Sin. Lumuvila.

Heterophragma adenophyllum Seems.
Bom. Pullung, Warras; Mar. Panlag, Waras; Te. Bondugu; C. Adwinuggi, Bechadi.

Hevea braziliensis Muell-Arg.
E. Para Rubber.

Hewittia bicolor W. & A. = *H. sublobata* O. Kuntze.
H. Jarad kalmi; Sin. Waltrastavalu.

Hibiscus cannabinus L.
E. Madras hemp, Deccan hemp; B. Mestapat; H. Patwa, Patsan; O. Kanuriya; P. Sankokra; Mar. Ambada; M. Kanjaru; T. Kachurai; Te. Gogu, Gonkura.

Hibiscus esculentus L. = *Abelmoschus esculentus* Moench.
E. Lady's Finger, Ram's Horn; S. Gandhamula; B. Dehras; H. Bhindi, Ramturai; U. Bhendi; A. & O. Bhendi; G. Bhindu; Bom. Bhenda; M. Vanta, Vendakka; T. Vendi, Vendikai; Te. Benda; C. Bende; Sin. Bandakka.

Hibiscus mutabilis L.
E. Changeable Rose; B. & A. Sthalpadma; H. Thalkamal; U. Guliajaib; O. Thalopodmo; T. Sembarattai; M. Chinapparatti; C. Suryakanti.

Hibiscus rosa-sinensis L.
E. China Rose, Shoe flower; S. Padmacharini; B. Jaba; H. Gurhal, Jasut; A. Joba; O. Mondaro; G. Jasuva; Bom. Jasavanda; Mar. Jassvandi; M. Japa; T. Mandaram, Sevarattai; Te. Dasani, Japapushpamu; C. Dasavala, Nadeya; Sin. Sapatthumal; Bur. Koungyan.

Hibiscus sabdariffa L.
E. Rozelle; B. Mesta; H. Kudrum, Lalpatwa; A. Mesekatenga; O. Khatakaunria; Bom. Lalambari; M. Polechi; T. Simaikkasuru; Te. Shimagonguru; Sin. Ratabilincha; Bur. Chinbaung.

Hibiscus tiliaceus L.
E. Tree Mallow; B. Bhola; H. Bola; O. Bariya; M. & T. Nirparutti; Sin. Belipatta; Bur. Thengben.

Hibiscus vitifolius L.
B. Bonkapas.

Hodgsonia heteroclita Hook. f.
B. Gulur; H. Til-lau.

Holarrhena antidysenterica Wall.
E. Easter tree; S. Girimallika, Kutaja; B. Kurchi; H. Karra, Kaura; A. Dudcory; O. Kherwa, Indraja; P. Kewar; G. Dhowda; Bom. Dolakura; Mar. Kodaga, Kurra; M. Kotakappala; T. Kulappalai, Veppalai; Te. Amkudu, Kodaga; C. Kudsalu, Korchu; Bur. Let-top-gyee.

Holmskioldia sanguinea Retz.
H. Kapni.

Holoptelea integrifolia Planch.
H. Papri, Chilmil; O. Dharango; P. Kacham, G. Kanjho; Mar. Papara, Vavli; M. Aval; T. Avali, Kanji; Te. Nemali, Tapasi; C. Kaladri; Sin. Dadahirilla; Bur. Myaukseik.

Hordeum vulgare L.
E. Barley; S. Yava; B. & A. Jab; H. Jau, Jawa; U. Jav; O. Jobo; P. Thanzatt, Chak; G. Jau; Bom. Jav, Satu; Mar. Java, Satu; T. Barliyarisi; Te. Vava, Barlibiyam; C. Javegodhi; Bur. Muyau.

Hoya parasitica Wall.
E. Wax flower; B. Paragacha.

Hydrilla verticillata Casp.
B. Jhanji.

Hydrocera triflora W. & A.
B. Domuti.

Hydrocotyle asiatica L. = *Centella asiatica* Urban.
E. Indian Pennywort; S. Mandu-

Kaparni, Brahmamanduki; *B.* Thankuni, Thulkuri; *H.* Brahmamanduki, Thalkuri; *U.* Brahmi; *A.* Manimuni; *O.* Thulkadi; *G.* Barmi; *Bom.* Karinga; *Mar.* Brahmi; *M.* Kodagam; *T.* Vallarai; *Te.* Babassa; *C.* Vondelaga; *Sin.* Hingotukola; *Bur.* Minkuabin.

Hygrophila spinosa T. And. = *Asteracantha longifolia* Nees.
S. Kokilaksha; *B.* Kuleykhara; *H.* Gokhulakanta, Kailaya; *U.* Talimkhana; *G.* Gokhru, Eharo; *Bom.* Kolsunda, Talimkhana; *Mar.* Talimakhana, Vikhara; *M.* Vayalchulli; *T.* Nirmalli; *Te.* Nirguvivera; *C.* Kalavankabija; *Sin.* Katreiriki.

Hyoscyamus niger L.
E. Henbane; *S.* Madakarini; *B.* Khorasaniajowan; *H.* Khurosaniyayamani; *U.* Khorasaniajwar; *P.* Bangidewana; *G.* Khorasaniajmo; *Bom.* Khorasaniowa; *Mar.* Khorasanivova; *T.* Kurasaniyomam; *Te.* Kurashanivamam; *C.* Khurasanivoma.

Hyptis suaveolens Poit.
O. Gangatulsi.

Iberis odorata L.
E. Candytuft.

Ichnocarpus frutescens R. Br.
S. Shyama; *B.* Shyamalata; *H.* Kalidudhi; *O.* Syamolota; *Mar.* Kantebhouri; *M.* Palvalli; *T.* Udargodi; *Te.* Nallatige; *C.* Gorwiballi; *Sin.* Kirivel; *Bur.* Tansapai.

Impatiens balsamina L.
E. Balsam; *S.* Swipatra; *B.* Dopati, Hajraphul; *H.* Gulmendi; *U.* Gulemendi; *A.* Damdenka; *O.* Haragoura; *P.* Bantil, Tatura; *G.* Pantambol; *Mar.* Terada; *T.* Kasithumbai; *C.* Gaurihu; *Sin.* Kudalikola; *Bur.* Dandalet.

Imperata arundinacea Cyrill.
B. Ulu; *H.* Dirghugas.

Indigofera linifolia Retz.
B. Bhangra; *H.* Torki; *G.* Jhinkigali; *Bom.* Burbura; *Mar.* Bhangra.

Indigofera tinctoria L.
E. Indigo; *S.* Nili; *B. & A.* Nil; *U.* Nila; *O.* Nilo; *G.* Gali; *Bom.* Nilaguli; *Mar.* Nili; *M.* Nilam; *T.* Avuri, Nilam; *Te.* Aviri, Nili; *C.* Ajara; *Sin.* Nilaiwara; *Bur.* Mai-nai.

Ionidium suffruticosum Ging. = *Hybanthes enneaspermus* F. V. Muell.
S. Charati; *B.* Nunbora; *H.* Ratanpurus; *Bom.* Ratanpuras; *M.* Orelatamara; *T.* Orilaitamarai; *Te.* Suriyakanti.

Ipomoea batatas Lamk. = *Batatas edulis* Choisy.
E. Sweet Potato; *S.* Kandagranthi; *B.* Ranga-alu, Misti-alu; *H.* Shakarkandi; *U. & P.* Shakarkanda; *A.* Boga-alu; *O.* Chinialu, Kandamula; *G.* Sakaria; *Bom.* Ratalu; *Mar.* Ratali; *M.* Kapakalenga; *T.* Vallikilangu; *Te.* Chelagada; *C.* Genasu; *Sin.* Batala; *Bur.* Kazwan.

Ipomoea biloba Forsk.
E. Goat's foot creeper; *S.* Maryada; *B.* Chagalkarui; *H.* Dopatilata; *O.* Kansarinata; *G.* Mariadavela; *Bom. & Mar.* Marjadvel; *M.* Atampa; *T.* Adambu, Adappangode; *Te.* Bedatige; *C.* Adumbaballi; *Sin.* Mudu-bin-tamburu; *Bur.* Pinlaikazum.

Ipomoea bona-nox L. = *I. alba* L.
E. Moon flower; *S.* Chandrakanti; *B.* Kalmilata, Halkalmi; *H.* Dudhikalmi, Chandrakant; *Bom.* Gulchandni; *M.* Mandavalli; *T.* Alangi, Nagamukkori; *Te.* Nagaramukkatte; *C.* Chandrakanti; *Sin.* Alanga; *Bur.* Nwekazumbyi.

Ipomoea hederacea Jacq.
E. Indian Jalap; *S.* Krishnabija; *B.* Nilkalmi; *H.* Kaladana; *U. & Bom.* Kaladanah; *O.* Kanikhondo; *P.* Bildi; *Mar.* Nilpushpi; *T.* Kodikakkatan; *Te.* Kolli; *C.* Tali.

Ipomoea pes-tigridis L.
E. Tiger's Foot; *B.* Langulilata; *O.* Bilaipado; *P.* Ishqpechan; *M.*

Pulichuvatu; *T.* Punaikkirai; *Te.* Puritikada; *Sin.* Diviadiya.

Ipomoea pulchella Roth. = *I. carica* Sw.
E. Morning Glory, Railway Creeper; *B.* Rel-lata.

Ipomoea reptans Poir. = *I. aquatica* Forsk.
E. Water Bindweed; *S.* Kalambi; *B.* Kalmishak; *H.* Karmi, Patuasaga; *U.* Narikakal; *A.* Kalamau; *O.* Kalamasaga; *P.* Nali; *G.* Nalanibhaji; *Bom.* Nalichibaji; *Mar.* Nadishaka; *T.* Koilangu; *Te.* Tutikura; *Sin.* Kankun.

Ischaemum angustifolium Hack.
E. Sabai grass.

Ixora coccinea L.
E. Flame of the woods; *S.* Raktaka, Bandhuka; *B.* & *A.* Rangan; *H.* Raktak, Kotagandhal; *O.* Romoniphulo; *Bom.* Bakoral, Abuli; *Mar.* Pankul, Bakora; *M.* Shetti; *T.* Setti, Vedji; *Te.* Bandhukamu, Korani; *C.* Kepala, Kisukare; *Sin.* Ratambala; *Bur.* Pansayeik.

Ixora parviflora Vahl. = *I. arborea* Roxb.
E. Torch tree; *S.* Nevali; *B.* Shet rangan; *H.* Makrichijhar, Nevari; *O.* Telokrya; *G.* Nevari; *Bom.* Kurat, Raikuri; *Mar.* Khura, Raikora; *T.* Koran, Sulundu; *Te.* Kori, Puttupala; *C.* Gorvi, Suragi; *Sin.* Maharatambala; *Bur.* Pansayeip.

Jasminum auriculatum Vahl.
E. Jasmine; *S.* Yuthika; *B.* Jui, Janti; *O.* Bonomollika; *C.* Hurinaballi; *T.* Vanamalligai; *Te.* Magadhi, Sudimalle.

Jasminum grandiflorum L.
E. Spanish Jasmine; *S.* Jati; *B.* Jati; *H.* Chameli; *U.* & *P.* Chambeli; *O.* Chombeli, Jati; *G.* & *Bom.* Chambeli; *M.* Malati; Pichakam; *T.* Kodimalligai, Pichi; *Te.* Jaji; *C.* Ajjige, Jati; *Bur.* Myatloe.

Jasminum pubescens Willd.
E. Downy Jasmine; *S.* Kunda; *B.* Kunda, Kundphul; *H.* Kunda; *O.* Kontabelo; *Mar.* Mogra; *M.* Kundam, Gu'ari; *T.* Malligai; *Te.* Kundamu, Molla; *C.* Kunda, Molle; *Bur.* Sabe.

Jasminum sambac L.
E. Arabian Jasmine; *S.* Mallika, Vanachandrika; *B.* Banmallika, Belphul; *H.* Bel, Motia; *U.* Raibel; *O.* Belophulo, Molli; *P.* Mugra; *G.* Mogro; *Bom.* Mogri; *Mar.* Mogra; *M.* Mallika; *T.* Malli; *Te.* Malle; *C.* Mallige; *Sin.* Pichchimal; *Bur.* Mali, Sabay.

Jatropha curcas L.
E. Physic nut, Purging nut; *S.* Parvateranda; *B.* Bagbharenda; *H.* Safedarand; *A.* Bongaliara; *O.* Baigoba; *G* Jamalgota; *Bom.* Irundi, Jepal; *Mar.* Mogalieranda; *M.* Kattavanaku; *T.* Adalai, Kattukkottai; *Te.* Adaviyamudamu, Pepalemu; *C.* Adaluharalu; *Sin.* Erandu; *Bur.* Thinbankyekku.

Jatropha glandulifera Roxb.
S. Nikumbha; *B.* Lalbharenda; *H.* Janglierandi; *O.* Simanorakokalo; *Bom.* Janglierandi, Undarbibi; *Mar.* Jangliarandi; *M.* Nakadanti; *T.* Kattamanaku; *Te.* Dundigamu; *C.* Tottagida.

Jatropha gossypifolia L.
S. Sayambara; *B.* Lalbharenda; *H.* Laleranda; *A.* Bothara; *O.* Rangakalo; *M.* Simayavanakku; *T.* Kattamanakku; *Te.* Simanepalemu; *C.* Kariturukaharalu.

Juncella inundatus C. B. Clarke.
B. & *H.* Pati.

Jussaea repens L.
B. Keshardam; *H.* Kes-ara; *A.* Taljuria; *M.* Nirgrampu; *T.* Mirkurambu; *Te.* Niruyagnivendaramu; *Sin.* Berudiyanilla.

Jussaea suffructiosa L.
S. Bhulavanga; *B.* Lalbonlabanga; *O.* Bilolobongo; *Mar.* Panalavanga; *M.* Karyampu; *T.* Nirkkrambu; *Te.* Niruyagnivendramu; *C.* Kavakula; *Sin.* Haemarägo.

Justicia betonica L.
Sin. Sudupuruk.

Justicia gendarussa L. f.
S. Nilanirgundi; *B.* Jagatmadan; *H.* Nilinargandi; *O.* Kukurodonti; *Bom.* & *Mar.* Kalaadulsa, Tao; *M.* Karinochil; *T.* Karunochi; *Te.* Nallanochili; *C.* Nachukaddi; *Sin.* Kaluvarania; *Bur.* Bawanet.

Kaempferia rotunda L.
S. Bhuchampaka; *B.* & *H.* Bhuichampa; *G.* Bhuichampo; *Mar.* Bhuichampa; *T.* Kondakalava; *Te.* Kondakalava; *C.* Nalasampige; *Sin.* Lukenda.

Kalanchoe spathulata DC.
S. Hemasagara; *B.* Himsagar; *H.* & *P.* Haiza, Rungru; *Bom.* Parnathij; *T.* Malakalli.

Kandelia rheedi W. & A.
B. Koria; *O.* Rasunia; *M.* Kantal; *T.* Kandal; *Te.* Kandigala; *C.* Kandale.

Kleinhovia hospida L.
E. Tree Antigonon; *B.* Bola.

Kydia calycina Roxb.
H. Potari, Pula; *O.* Bharimo; *P.* Pola, Puli; *G.* Mothinirwani; *Bom.* Motipotari; *Mar.* Potari; *M.* Velukku; *T.* Vendai; *Te.* Kondapatari; *C.* Belagu; *Bur.* Bokemaiza.

Kyllinga brevifolia Rottb.
S. Nirvisha; *B.* Bindimuthi; *H.* Nirbisi; *Mar.* Mostu; *M.* Kolpullu.

Lactuca sativa L.
E. Garden Lettuce; *B.* Letush; *H.* Salad; *U.* Kahu; *T.* Sabattu; *Te.* Kavu; *Sin.* Salada.

Lagenaria vulgaris Ser.
E. Bottle Gourd; *S.* Alabu; *B.* & *O.* Lau; *H.* Kaddu, Lauki; *U.* Tumbari; *A.* Bogalao; *P.* Golkaddu; *G.* Dudhi; *Bom.* Karwabopla; *Mar.* Bhopla; *M.* Bellashora; *T.* Shorakkai; *Te.* Alaburu; *C.* Kahesore; *Sin.* Diyalabu; *Bur.* Businswai.

Lagerstroemia flos-reginae Retz = *L. speciosa* Pers.
E. Crepe Myrtle, Indian Lilac; *B.* Jarool; *H.* Jarul; *A.* Ajhar; *O.* Jarulo; *Bom.* Taman; *Mar.* Motabondara; *M.* Nirventekku; *T.* Kadali; *Te.* Varagogu; *C.* Maruvachalla, Hobdachalla; *Sin.* Murute; *Bur.* Pyinma.

Lagerstroemia thorellii Gagnep.
B. Belati jarool; *Bom.* Dhayti; *T.* Sinappu; *Te.* Chinagoranta.

Lantana indica Roxb.
B. Chotra; *H.* Aripple; *G.* Ghanidalia; *Mar.* Ghaneri; *M.* Arippu; *T.* Unni, Makkadambu; *C.* Joli, Parale; *Sin.* Gandapana, Tonkinna.

Lathyrus aphaca L.
E. Wild Pea; *B.* Bonmatar; *H.* Janglimattar; *O.* Jangalimatar; *P.* Rawan, Rawari.

Launea asplenifolia Hook. f.
B. & *H.* Tikchana.

Launea pinnatifida Cass.
H. Bankau; *G.* Bhoupatri; *Bom.* Pathri; *Mar.* Pathradi, Paththa.

Lawsonia alba Lam. = *L. inermis* L.
E. Henna plant, Indian Privet; *S.* Mendhika, Raktagarbha; *B.* Mehedi; *H.* Mehndi; *U.* Mehendi; *O.* Rangota; *P.* Hinna; *G.* Medi; *Bom.* & *Mar.* Mendi; *M.* Mavilanji; *T.* Marudondri, Aivanam; *Te.* Goranta; *C.* Gorante; *Sin.* Maritondo; *Bur.* Danbin.

Lawsonia indica L.
B. Purush.

Leea aequata L.
S. Dasi, Kakangsika; *B.* & *H.* Kakjangha; *G.* Aghedi; *Mar.* Kanga; *M.* Kakanasika; *Te.* Surapadi; *C.* Jirichilecha; *Bur.* Nagamauk.

Leea macrophylla Hornem.
S. Samudraka; *B.* Dholsamudra; *H.* Hatikan; *Bom.* & *Mar.* Dinda.

Lens esculenta Moench. = *L. culinare* Medic.
E. Lentil; *S.* Masurika; *B.* Musuri; *H.* & *U.* Masur; *A.* Masurmoha; *O.* Mosura; *G.* Mosuridal; *Mar.* Masura; *T.* Misurpurpur; *Te.* Misurpappu; *C.* Massur.

Leonotis nepetifolia R.Br.
B. & H. Hejurchei; *G. & Bom.* Matijer, Matisul; *Mar.* Dipmal; *Te.* Ranabheri; *Sin.* Mahayakwanassa.

Leonurus sibiricus L.
E. Motherwort; *B.* Raktodrone; *H.* Halkusha, Guma; *A.* Rongadoron; *O.* Kuilekha, Bhutaairi; *Mar.* Kamba; *Te.* Enugutummi.

Lepidium sativum L.
E. Garden Cress; *S.* Chandrika, Raktabija; *B.* Halimsak; *H.* Chaunsar, Halim; *U.* Halim; *O.* Hidambasaga; *P.* Halim, Tezak; *G.* Asahio; *Bom.* Asalia; *Mar.* Ahliva; *T.* Ativerai; *Te.* Adiyalu, Adeli; *C.* Allibija; *Bur.* Mongnyin.

Leucas aspera Spreng.
S. Dandakalash; *B.* Shetadrone, Ghalghase; *H.* Chotahalkusa; *A.* Doron, Durumphul; *O.* Gaisa; *Bom.* Tamba; *M.* Thumpa; *T.* Tumbai; *Te.* Tummachettu, Tummikura.

Leucas linifolia Spreng. = *L. lavendulaefolia* Rees
S. Dronopushpi, Kumbhi; *B.* Halkasa; *H.* Halkusa, Kumbha; *U.* Guma; *A.* Dron; *C.* Jhinanpannikubo; *Mar.* Kuva; *Te.* Pulatumni.

Ligustrum robustum Bl.
E. Privet.

Limnanthemum cristatum Griseb.
B. Panseuli; *Sin.* Hinamtala.

Limnophila gratioloides R.Br.
S. Ambuja; *B.* Karpur; *H.* Kuttra; *M.* Manganari; *Mar.* Ambuli.

Linaria ramosissima Wall.
E. Toadflask; *G.* Bhintgalodi, Kanodi.

Lindenbergia urticaefolia Link. & Otto
B. Basanti; *G.* Bhintachati; *Bom.* Gazdar; *Mar.* Dhol, Gajkdra.

Linum usitatissimum L.
E. Flax; *S.* Masina; *B.* Tisi; *H.* Alsi, Tisi; *U.* Alesi; *P.* Alish, Alsi; *G.* Alshi; *Mar.* Alashi, Javasa; *M.* Cheruchanaviltintevilta; *T.* Alshi; *Te.* Alasi; *C.* Alashi.

Lippia nodiflora Rich. = *Phyla nodiflora* Green
S. Chitrapatri; *B. & H.* Bhuiokra; *O.* Bukkan; *P.* Bakkan, Jalnim; *G.* Ratoliya; *Bom.* Ratolia; *Mar.* Jalapimpali; *M.* Kattuttippali; *T.* Podutalei; *Te.* Bokenaku, Bokkena.

Litsea sebifera Pers.
E. Tallow Laurel; *S.* Adhavara, Meda; *B.* Kukur-chita, Gorur; *H.* Garbi-jaur; *O.* Jadamo; *Bom.* Chickana; *Mar.* Miri; *T,* Ama; *Te.* Meda; *Sin.* Bombi.

Lodoicea seychellarum Labill.
E. Double Coconut palm; *H.* Daryakanaryal; *G.* Daryanunariyal; *Bom.* Jaharinaral; *M.* Kataltenna; *T.* Kadattengai; *Te.* Samudraputenkaya; *Sin.* Mudupol; *Bur.* Penle-on-si.

Luffa acutangula Roxb.
S. Jhingaka; *B.* Jhinga; *H.* Jinga, Torai; *U.* Torai; *O.* Janhi; *G.* Gonsali; *Bom.* Jinga, Turai; *Mar.* Dodaki, Shirola; *M.* Dinji; *T.* Pikunkai; *Te.* Burkai; *C.* Hirekayi; *Sin.* Vetakola; *Bur.* Thapwot.

Luffa aegyptiaca Mill. = *L. cylindrica* M. V. Roem
E. Sponge Gourd; *S.* Ghoshaka; *B.* Dhundul; *H.* Ghiatarui; *U.* Turi; *A.* Bhatkerela, Bhol; *P.* Ghiatori; *G.* Turia; *Bom.* Ghosali; *Mar.* Paroshi; *T.* Pikku; *Te.* Guttibira; *Sin.* Neyangnattakolu; *Bur.* Thabwot.

Lycopersicum esculentum Mill.
E. Tomato; *B.* Belatibegun; *H.* Tamatar.

Machilus villosa Hook. f.
C. Chittutanti; *M.* Puravu; *T.* Anaikkuru; *Sin.* Ululu.

Magnolia grandiflora L.
E. Lily tree; *B.* Udaypadma; *H.* Himchampa.

Magnolia pterocarpa Roxb.
B. & H. Duleechampa.

Mallotus philippinensis Muell.-Arg.
E. Monkeyface tree; *S.* Kapila,

Ranjaka; *B.* Kamila; *H.* Kamela; *U.* Kalileh; *A.* Gangai; *O.* Kopilogundi; *G.* Kapilo; *Bom.* Kapila; *Mar.* Shindur; *M.* Ponni; *T.* Kopilapodi; *Te.* Sinduri; *C.* Kunkuma; *Sin.* Hamparila. *Bur.* Tanthieden.

Malva riscus L.
B. Lankajaba.

Mangifera indica L.
E. Mango; *S.* Ambrah; *B. & H.* Am; *U. & O.* Amba; *A.* Ghariam; *P.* Amb, Mawashi; *G.* Ambo, Amri; *Bom.* Amba, Ambo; *Mar.* Amba; *M.* Amram; *T.* Ambiram, Mamagam; *Te.* Amramu, Mamidi; *C.* Mavu; *Sin.* Etamba; *Bur.* Thayet.

Manihot utilissima Pohl.
E. Cassava, Tapioca; *C.* Maragenosu; *Sin.* Manyokka; *Bur.* Pooloopinanmyouk.

Maranta arundinacea L.
E. Arrowroot plant; *B.* Araroot; *H.* Tikhor; *T.* Aruruttukkilangu; *Te* Palagunda; *Sin.* Hulankiriya; *Bur.* Pen-bwa.

Marsdenia tenacissima W. & A.
B. Jitti; *H.* Tongus.

Marsilea quadrifolia L.
B. Sushnishak; *A.* Panitengechi; *O.* Sunsunia; *M.* Nalilakkotan; *T.* Arakkodai; *Te.* Chiktitakura.

Martynia diandra Glox
E. Tiger's claw; *B.* Baghnoki; *H.* Shernui, Bichu; *U.* Hattajori; *A.* Baghnakhi; *O.* Baghanokih; *P.* Bichu. Hattajori; *M.* Pulinagam; *T.* Nagathali; *Te.* Garudamukku; *Sin.* Nagadarana.

Medicago denticulata Willd.
B. & H. Maina.

Melaleuca leucadendron L.
E. Cajeput oil tree; *B.* Cajuputte; *H.* Kayaputi; *Mar.* Cajuputa; *Te.* Kaiyapuddai ; *Sin.* Lothsumbul.

Melastoma malabathricum L.
E. Indian Rhododendron; *A.* Futki; *O.* Koroti; *Mar.* Palore; *M.* Katali; *T.* Kadalai; *Te.* Pattudu; *C.* Kenkarike; *Sin.* Katakaluwa; *Bur.* Myetype.

Melia azadirachta L. = *Azadirachta indica* A. Juss.
E. Neem tree, Margosa tree; *S.* Nimba; *B.* Nim; *H.* Nimb; *U.* Neem; *A.* Mohanim; *O.* Nimbo; *P.* Bakam, Nim; *G.* Limbado; *Bom.* Bakayan, Nim; *Mar.* Limba; *M.* Veppu. Nimbam; *T.* Vembu; *Te.* Yeppa; *C.* Nimba; *Sin.* Kohumba; *Bur.* Tha-ma-ka.

Melia azedarach L.
E. Persian Lilac; *S.* Mahanimba; *B.* Ghoranim; *H.* Mahanimb, Bakayan; *U.* Bakayana; *A.* Thamaga; *O.* Mahanimbo; *P.* Bakain; *G.* Bakanlimbodo; *Bom.* Mahalimbo; *Mar.* Bakananimb; *M.* Malaveppu; *T.* Malaivembu, Tittam; *Te.* Vettiveppa; *C.* Bevu; *Sin.* Mahanimba; *Bur.* Tha-ma-kha.

Melilotus alba Lamk.
E. White Melilot; *S.* Methika; *B.* Sadamethi; *H.* Safed methi.

Malachra capitata L.
B. Bondhenros; *H.* Banbhindi; *Bom.* Bonbhendi; *Mar.* Ranbhendi.

Melilotus indica All.
E. Small Melilot; *S.* Vanamethika; *B. & H.* Banmethi; *P.* Sinjee.

Melochia corchorifolia L.
B. Tikiokra; *O.* Nolita; *M.* Seruvuram; *T.* Punnakkukhirai; *Te.* Sittantakura; *Sin.* Galkura.

Memecylon edule Roxb.
E. Iron wood tree; *S.* Anjani; *O.* Bonohorono; *Bom.* Anguni; *Mar.* Anjani, Kurpa; *M.* Kayavu; *T.* Anjani, Pungali; *Te.* Midalli; *C.* Alle; *Sin.* Dedikaha; *Bur.* Myenphaetenyet.

Mentha viridis L.
E. Mint; *B. & P.* Pudina; *H.* Podina; *G.* Phudino; *Bom.* Pudinah; *Mar. & Te.* Pudina; *M.* Putiyina; *T.* Jech-chak-kirai; *C.* Chetnimaragu; *Sin.* Meenchi.

Meriandra benghalensis Benth.
E. Bengal Sage; *H.* Kafurkapat;

Bom. Kafurkapatha, Sesti; *T.* Sayayitai; *Te.* Simakarpuramu.

Merremia emarginata Hook. f.
S. Mushakarni; *B.* Indurkanipana; *H.* Musakani; *U.* Chukakani; *G.* Undarakani; *Bom.* Undirkani; *T.* Perettaikkiray; *Te.* Toinnuatali.

Mesua ferrea L.
E. Ironwood; *S.* Nagakesara; *B.* Nageswar; *H. & P.* Nagkesar; *U.* Narmiskha; *A.* Nahor; *O.* Cagokesoro; *Bom. & Mar.* Nagchampa; *M.* Nagachempakam; *T.* Nagesuram; *Te.* Nagakessaramu; *C.* Nagakessara; *Sin.* Deyana; *Bur.* Kengau.

Michelia champaca L.
E. Golden champa; *S.* Champaka; *B.* Swarnachampa; *H. & P.* Champa; *A.* Phulchopa; *O.* Chompa; *G.* Pitochampo; *Bom.* Champa; *Mar.* Sonachampa; *M.* Champakam; *T.* Senbagam; *Te.* Champakmu; *C.* Champaka; *Sin.* Champak; *Bur.* Changal, Saga.

Mikania scandens Willd.
E. Climbing Hempweed; *B.* Taralata; *Sin.* Gampalu.

Mimosa pudica L.
E. Sensitive plant; *S.* Anjalikarika; *B.* Lajjabati; *H.* Lajwanti, Chuimui; *A.* Lajukilata; *O.* Lajokoli; *P.* Arlu; *Mar.* Lajri; *M.* Tottavadi; *Te.* Nidrabhangi; *C.* Lajja; *Sin.* Nidikumba; *Bur.* Nti-kha-yone-bin.

Mimusops elengi L.
E. Elengi, Indian Medlar; *S.* Vakula; *B.* Bakul; *H.* Mulsari; *U.* Molsari; *O.* Bokulo; *G.* Bolsari; *Bom.* Borsali; *Mar.* Ovalli; *M.* Bakulam, Elengi; *T.* Vagulam, Lanji; *Te.* Pogade, Vakalamu; *C.* Vakula; *Sin.* Munemal; *Bur.* Kaya.

Mirabilis jalapa L.
E. Marvel of Peru, Four o'clock plant; *S.* Sandhyakoli; *B.* Krishnakoli, Sandhyamoni; *H.* Gulabbas; *U.* Guleabbas; *A.* Godhuligopal; *O.* Krishnakolika; *Bom.* Gubhaji; *Mar.* Gulbas; *M.* Antimalari; *T.* Antinarulu; *Te.* Chandramalli; *C.* Chandramallige; *Sin.* Sendrikka; *Bur.* Mizubin.

Modecca palmata Lamk.
M. Mutakku; *Te.* Modikka; *Sin.* Hondala.

Momordica charantia L.
E. Bitter Gourd; *S.* Karavella; *B.* Karala; *H.* Kareli; *U.* Karella; *A.* Kakrali; *O.* Karena; *G.* Karelu; *Bom.* Karla; *Mar.* Karale; *M.* Kaippa; *T.* Pakal; *Te.* Kakara; *C.* Hagola; *Sin.* Kirilla; *Bur.* Kyethenka.

Momordica cochinchinensis Spreng.
S. Karkata; *B.* Kakrol; *H.* Gulkakra; *U.* Kakrol; *G.* Karapata; *Mar.* Kakana; *Te.* Adavikakara; *Bur.* Samongnway.

Morinda citrifolia L.
E. Indian Mulberry; *S.* Achchhuka; *B.* Auch; *H.* Ach; *O.* Achu; *G.* Alsaraoji; *Bom.* Aal, Nagakuda; *Mar.* Bartondi, Nagakunda; *M.* Mannanatti; *T.* Manjanatti, Nuna; *Te.* Mulugu, Togaru; *C.* Maddi, Tagase; *Sin.* Ahugaha; *Bur.* Nyahgyi.

Morus indica L.
E. Mulberry; *S.* Tuta; *B.* Toont; *H.* Toot, Tutri; *U.* Sahetuta; *A.* Numi; *O.* Tuto; *P.* Tut; *G.* Shetur; *Bom.* Tutri, Ambor; *Mar.* Ambat, Tut; *M.* Tulam; *T.* Kambali, Musukattai; *Te.* Putikainerale; *Bur.* Posa.

Mucuna pruriens Bak.
E. Cowhage plant; *S.* Atmagupta; *B.* Alkushi; *H. & P.* Kawanch; *U.* Kavancha; *O.* Alokushi; *G.* Kivanch; *Bom.* Kuhili; *Mar.* Kavacha, *M.* Shoriyanam; *T.* Amudari, Punaikkali; *Te.* Dubagoudi; *C.* Kadavare; *Sin.* Achariyapalle; *Bur.* Khuele.

Mukia scabrella Arn.
B. Billari; *H.* Agumaki; *M.* Mukkalpiran; *T.* Musumusukkai; Te. Kutarubudama; *Bur.* Sathakhiva.

Murraya exotica L. = *M. paniculata* Jack.
E. Chinese Box; *B.* Kamini; *H.* Marchula, Kamini; *A.* Kaminiphul; *O.* Poudoka; *Bom. & Mar.* Manchulajuti; *M.* Marmulla; *T.* Kariveppilai; *Te.* Nagagolugu; *C.* Nagadala; *Sin.* Etteriya; *Bur.* Thanatkha.

Murraya koenigii Spreng.
E. Curryleaf tree; *S.* Girinimba, Suravi; *B.* Barsunga; *H.* Katnim, Bursunga; *O* Basango; *P.* Bowala; *Bom.* Karriapat; *Mar.* Karipat; *M.* Kareapela; *T.* Karuvippilai; *Te.* Karepeku; *C.* Karibevu; *Sin.* Karapincha; *Bur.* Pindosin.

Musa paradisiaca L.
E. Plantain; *B.* Kanchkala; *H.* Kachakela; *M.* Kadalam. Vala; *T.* Valai; *Te.* Arati; *C.* Bale; *Sin.* Kehel.

Musa sapientum L.
E. Banana; *S.* Rambha. Kadali; *B.* Kala; *H. & U.* Kela; *A.* Kolpaka; *O.* Kodoli; *G. & Bom.* Kela; *Mar.* Kadali, Kel; *M.* Kadalam; *T.* Kadali, Kavar; *Te.* Kadalamu, Rambhha; *C.* Budibale; *Sin.* Kehel; *Bur.* Yathilan.

Mussaenda frondosa L.
S. Nagaballi; *H.* Bedina; *Bom.* Bebana; *Mar.* Shivardole; *T.* Bedina; *Bom.* Bebana; *Mar.* Shivadole; *T.* Vellimadandai; *M.* Vellila; *C.* Bellotti; *Sin.* Maasenda; *Bur.* Ywethla.

Myrtus communis L. = *Acmena communis* Merr. & Perry.
E. Myrtle; *B.* Belatimehedi; *H. & P.* Vilayatimehndi, Murad; *U.* Habulas; *T.* Kulinaval.

Naravelia zeylanica DC.
E. Traveller's Joy; *B.* Chagalbati; *H.* Chagoolbatee; *Te.* Mukkupinatatega.

Nasturtium indicum DC. = *Rorippa montana* Small
E. Water Cress; *B.* Bilrai; *Sin.* Kakutupala.

Nelumbium speciosum Willd. = *Nelumbo montana* Small
E. Lotus; *S.* Kamala, Padma; *B.* Padma; *H.* Kamal; *U.* Nilofer; *A.* Podum; *O.* Padam; *P.* Kanwal; *G.* Surivakamal; *M.* Tamara; *T.* Ambal. Thamarai; *Te.* Allita-mara. Tamara; *C.* Tavarigadde; *Sin.* Nelum; *Bur.* Padungma.

Nephelium litchi Camb. = *Litchi chinensis* Sonner.
E. Litchi; *B.* Lichu; *H.* Litchi; *U.* Lichur; *O.* Lishi; *Bom.* Lichi; *T.* Illichi, Tarain; *Bur.* Kiak-mauk.

Nephelium longana Camb. *Euphoria longana* Lamk.
E. Longan; *B.* Ansphal; *Bom.* Wumb; *Mar.* Vomb; *T.* Kattupuvam; *C.* Malehakuta; *Sin.* Mora. Murale; *Bur.* Tawthayet.

Neptunia oleracea Lour.
B. Panilajuk; *H.* Lajalu; *Bom.* Panilajak; *M.* Nittitoddavaddi; *T.* Sundaikkirai; *Te.* Nidrayam; *Sin.* Diyanidikumba.

Nerium odorum Soland. = *N. indicum* Mill.
E. Oleander; *S.* Karavira; *B.* Karabi; *H. & P.* Kaner; *U.* Kanir; *O.* Konero; *G.* Kanera; *Bom.* Kanhera; *Mar.* Kaneri; *M.* Arali, Kanaviram; *T.* Karaviram, Alari; *Te.* Kasturipatta, Ganneru; *C.* Kanagile; *Sin.* Araliya.

Nicotiana plumbaginifolia Viv.
B. Bontamak; *H.* Bantamaku.

Nicotiana tabacum L.
E. Tobacco; *S.* Tamrakutta; *B.* Tamak; *H.* Tamaku; *U.* Tambaku; *A.* Dhopat; *O.* Dhuanpatra; *G. & Mar.* Tamaku; *Bom.* Tambakhu; *M.* Pokala, Pukayila; *T.* Pugailai; *Te.* Pogaku; *C.* Hogesappu; *Sin.* Dhumkola; *Bur.* Se, Ts-ay-bin.

Nigella sativa L.
E. Black Cumin, Fennel flower; *S.* Krishnajiraka; *B.* Kalojira; *H.* Kalonji, Kalajira; *Bom.* Kalonji; *T. & M.* Karunjiragam; *Te.* Nellajilakaira; *C.* Karijirigi; *Sin.* Kaluduru.

Nipa fruticans Wurmb.
E. Water Coconut; *B.* Golpata; *H.* Gulga; *G.* Pardeshitadio; *Te.* Nipamu; *Sin.* Gimpol.

Nyctanthes arbortristis L. = *Jasminum multiflorum* Andr.
E. Coral Jasmine, Sad tree; *S.* Sephalika, Parijataka; *B.* Seuli; *H.* Harisingar; *U.* Gulejafari; *A.* Sewaliphul; *O.* Singarharo; *P.* Pakura, Laduri; *G.* Javaparvati; *Bom.* Parijataka; *Mar.* Parijatak; *M.* Mannappu; *T.* Manjatpu, Pavelam; *Te.* Parijatham; *C.* Harisringi; *Sin.* Sepalika.

Nymphaea lotus L.
E. Waterlily, Pondilv; *S.* Kambal; *B.* Shalook, Shapla; *H.* Chotakamal; *P.* Nilofar; *G. & Mar.* Kanval, Kamal; *M.* Vellampal; *T.* Alli, Valjambal; *Te.* Allikada, Kaluva; *C.* Tavare; *Sin.* Olu; *Bur.* Kya-pin.

Nymphaea rubra Roxb.
E. Red Waterlily; *S.* Raktotpala, Indivara; *B.* Raktokamal; *G.* Kanval, Nilophar; *Mar.* Raktakamal; *M.* Ampala; *T.* Allitamarai, Ambal; *Te.* Allitamara, Koteka; *C.* Bilitavarai; *Sin.* Otu; *Bur.* Kiyani.

Nymphaea stellata Willd.
E. Blue Waterlily; *S.* Nilotpala; *B.* Nilpadma; *H.* Nilkamal, Nilpadma; *G.* Nilkamal; *Bom.* Upliakamal; *Mar.* Krishnakamal; *M.* Sitambel; *Te.* Nitikulava; *Sin.* Manel; *Bur.* Kyanyu.

Ocimum basilicum L.
E. Common Basil; *S.* Manjariki; *B.* Babuitulsi; *H.* Barbar; *U.* Janglitulshi; *O.* Dhalatulasi; *G.* Sabje; *Bom.* Sabja; *Mar.* Sabza; *M.* Pachcha; *T.* Tirunitru; *Te.* Rudrajada; *C.* Ramkasturi; *Sin.* Suwandutala; *Bur.* Pinzainpinzin.

Ocimum gratissimum L.
S. Ramatulasi; *B.* Ramtulsi; *H.* Bantulsi, Ramtulsi; *U.* Ramtulasi; *O.* Ramotulsi; *P.* Banjere; *Bom.* Ramatulasa; *G. & Mar.* Ramtulasi; *M.* Kattutrittavu; *T.* Elimuchantulasi; *Te.* Nimmatulasi; *C.* Ramkasturi; *Sin.* Otala.

Ocimum sanctum L.
E. Sacred Basil; *S.* Krishnamula; *B.* Kalotulsi; *H.* Krishnatulsi; *A.* Tulashi; *O.* Tulasi; *P.* Bantulsi; *G.* Talasi; *Bom & Mar.* Tulasa; *M.* Sivatulasi; *T. & Te.* Tulasi; *C.* Tulasigidda; *Sin.* Madurutala; *Bur.* Lun.

Odina woodier Roxb. = *Lannea coromandelica* Merr.
E. Indian Ash tree; *S.* Jivala; *B.* Jiyal, Jeuli; *H.* Jingan, Kaimil; *O.* Jiyolo; *P.* Kamlai; *G.* Mavedi; *Bom.* Gajel; *Mar.* Shimti; *M.* Oti; *T.* Odi; *Te.* Oddi; *C.* Godde, Udi; *Sin.* Hik; *Bur.* Hnanbai.

Oenanthe stolonifera Wall. = *O. javanica* DC.
B. Panturasi.

Olea europea L.
E. Olive tree; *T.* Saidun; *Te.* Jaitun; *C.* Julipe.

Oldenlandia corymbosa L.
S. Parpata; *B.* Khetpapra; *H.* Damanpapar; *O.* Gharpodia; *G.* Parpat; *Mar.* Papti; *T.* Parpadagaru; *Te.* Verinellavamu; *Sin.* Val-pat-paadagam.

Oldenlandia crystallina Roxb.
B. Panki.

Oldenlandia umbellata L.
B. & O. Surbuli; *H.* Chirval; *M.* Chayaver; *T.* Chiruver; *Te.* Cherivelu; *Sin.* Saya.

Opuntia dillenii Haw.
E. Prickly Pear; *S.* Nagaphana; *B.* Phanimonsa; *H.* Nagphani; *U.* Nagaphani; *A.* Sagorphena; *O.* Nagopheni; *P.* Chitarthor; *G.* Chorhathalo; *Mar.* Nagaphana; *M.* Nagamullu; *T.* Nagakalli; *Te. & C.* Nagadali; *Sin.* Kodugaha; *Bur.* Kalazaw.

Oroxylum indicum Vent.
E. Indian Trumpet flower; *S.* Shona; *B.* Sona; *H.* Arlu, Sauna; *U.* Arlu; *A.* Kering; *O.* Sono; *P.* Miringa; *G.* Podval, Tetu; *Bom.* Tetu, Ulu; *Mar.* Taitu, Ulu; *M.* Aralu; *T.* Arulandai; *Te.* Mokkavepa; *C.* Sonpatte; *Sin.* Totila; *Bur.* Kyaungya.

Oryza sativa L.
E. Paddy; *S.* Dhanya; *B. & O.*

Dhan; *H.* Chaul, Chaval; *P.* Munji; *G.* Chokha; *Bom.* Bhatta, Dangar; *Mar.* Bhat, Tandula; *M.* Ari; *T.* Nellu; *Te.* Biyam, Dhanyamu; *C.* Akki; *Sin.* Uruwi; *Bur.* Ṣa-ba-bin.

Ottelia alismoides Pers.
B. Parmikalla.

Ougeinia dalbergioides Benth.
E. Chariot tree; *S.* Tinashaka, Vanjula; *B.* Tinis; *H.* Sandan, Tinnas; *O.* Bandhono; *P.* Sannan; *G.* Tanasse; *Bom.* Tinsa, Tunnus; *Mar.* Tivas; *M.* Malavenna, Nemi; *T.* Narivengai; *Te.* Nemmi, Vanjubamu.

Oxalis corniculata L.
E. Indian Sorrel; *S.* Amlalonika; *B.* Amrulshak, Amboli; *H.* Amboti, Chalmori; *A.* Chengeritenga; *O.* Amliti; *P.* Amlika, Surchi; *Bom.* & *Mar.* Ambuti, Bhinsarapati; *M.* Poliyarala; *T.* Puliyarai; *Te.* Ambotikura, Pulichinta; *C.* Pullampurachisappu; *Sin.* Hinambulembiliya.

Oxystelma esculentum R. Br.
S. Dugdhika; *B.* Dudhi, Dudhialata; *H.* Dudhi, Dudlutta; *U.* Dudhi; *O.* Dudhai; *P.* Gani; *G.* Jaldudhi; *Bom.* Dudhika; *Mar.* Dudhari; *T.* Usippalai; *Te.* Dudipala; *C.* Dugdhike.

Paederia foetida L.
S. Prosarini, Gandhabhadra, Gandhali; *B.* Gandhabhaduli, Gandhal; *H.* Bakuchi, Gandhali; *U.* Gandhaa; A Bedailata; *O.* Gandali; *G.* Gandhana; *Bom.* Prasaram; *Mar.* Hiranvel, Prasarani; *M.* Talanili; *Te.* Savirela; *C.* Hesarane.

Pancrateum verecundum Ait.
B. Kumur; *M.* Cattulipola; *Te* Tellagata.

Pandanus fascicularis Lamk.
E. Screwpine; *S.* Ketaka; *B.* Keya, Ketuki; *H.* Keora, Keura; *U.* Keora; *A.* Ketakiphul; *O.* Ketoki, Kiya; *G.* Kewoda; *Bom.* Kenda, Keura; *Mar.* Keoda, Keora; *M.* Ketaki; *T.* Kedagi, Talhai; *Te.* Ketaki, Mogali; *C.* Kedige; *Sin.* Mudukeyiya; *Bur.* Tsatthapu.

Panicum miliaceum L.
E. Common Millet; *S.* China, Varaka; *B.* China; *H.* & *P.* Chena; *G.* Chino, Vari; *Bom.* Chenah, Sama; *Mar.* Vari, Barag; *T.* Varagu; *Te.* Varagalu; *C.* Baragu, Save; *Sin.* Mainairi.

Panicum miliare Lamk.
E. Little Millet; *B.* Gondula; *H.* Kungu; *P.* Kutki; *Bom.* Warai; *T.* Shamai; *Te.* Nellashamalu; *Sin.* Meneri.

Papaver somniferum L.
E. Opium Poppy; *S.* Ahiphena; *B.* Afing-gach, Posto; *H.* & *P.* Afin, Post; *U.* Khaskhassufaid; *A.* Afingoch; *O.* Aphimo; *G.* Aphina; *Bom.* Khaskhas, Post; *Mar.* Aphu; *M.* Khaskashachcheti; *T.* Postaka; *Te.* Abhini; *C.* Khasakhasi; *Sin.* Abin; *Bur.* Bhainzi.

Paramignya citrifolia Hook. f. = *Merope angulata* Swingle
B. Bon-nebu; *Bom.* Karivageti; *Mar.* Kariwageti; *C.* Kadukanji; *Sin.* Wellangiriya.

Parkinsonia aculeata L.
E. Jerusalem Thorn; *B.* Belatibabla; *H.* Vilayati kikar.

Passiflora foetida L.
E. Passion flower; *B.* & *H.* Jhumkolata; *O.* Jhumukolota; *Mar.* Krishnakamal; *M.* Kristhupazham; *T.* Siruppunaikkali; *Te.* Tellajumiki.

Pastinacea vera L.
E. Parsnip.

Pavetta indica L.
S. Papata; *B.* Kukurchura; *H.* Papari; *O.* Bonki; *Bom.* Papat; *Mar.* Papadi; *M.* Pavatta; *T.* Pavattai; *Te.* Papidi; *C.* Pavati; *Sin.* Pawatta; *Bur.* Hmitgyin.

Pavonia odorata Willd.
S. Vala; *B.* Bala; *H.* Sugandhabala; *G.* Kalowalo; *Bom.* & *Mar.* Kalavala; *M.* Kuruntotti; *T.* Peramutti; *Te.* Chittibenda; *C.* Mudivala.

Pedilanthus tithymaloides Poit.
E. Jew's slipper; *B.* Rangchita; *H.* Nagdaman; *O.* Bilatisiju; M. Verakkodi.

Peltophorum ferrugineum Benth. = *P. pterocarpum* Backer.
E. Caper Pod; *T.* Iyavakai.

Penisetum typhoideum Rich.
E. Pearl Millet; *S.* Varjarika; *B.* Bajra; *H.* Bajera, Bajra; *O.* Bajramula; *P.* Bajza; *Bom.* Bajri; *M.* Mathari; *T.* Kambu; *Te.* Sajjabu.

Pentapetes phoenicia L.
E. Noon flower; *S.* Suryabhakta; *B.* Surjyamoni, Dupureychandi; *H.* Dopohoria; *O.* Dopaharia; *P.* Guldupaharia; *G.* Duporio; *Bom.* Doopahuria; *Mar.* Tambridupari; *T.* Nagappu.

Pentatropis microphylla W. & A.
S. Suryavalli, Shringariti; *H.* Kanathodi, Ambarvel; *G.* Singroti, Suryavel; *Mar.* Shingrota; *T.* Uppili; *Te.* Pulapala.

Peperomia pellucida Kunth.
B. Luchipata.

Pergularia minor Andr. = *Telosma minor* Craib.
E. Cowslip creeper; *B.* Kunjalata.

Peristrophe bicalyculata Nees.
B. Nasabhanga; *H.* Itrelal, Nasbhanga; *G.* Kaliadhedi; *Bom.* Pitpatra; *Mar.* Rankireyat; *Te.* Chebira ; *Sin.* Mahanelu.

Petunga roxburghii DC.
B. Pitanga.

Peucedanum sowa Kurz. = *Anethum sowa* L.
E. Anet; *S.* Satapuspika, Shipha; *B.* Sulpa; *H.* Sowa; *U.* & *P.* Soya; *G.* Surva; *Bom.* & *Mar.* Shepu, Shupa; *T.* Satakkuppi; *Te.* Sompa; *Sin.* Sathakuppai; *Bur.* Samyeit.

Phaseolus aureus L.
E. Golden Gram; *B.* Sonamoog; *H.* Sonamung; *A.* Mogumah; *O.* Jhainmuga; *P.* Moong; *M.* Cherupayaru; *T.* Pachapayaru; *Te.* Pesalu.

Phaseolus mungo L.
E. Black Gram; *S.* Mudga; *B.* Mashkalai; *H.* Mung, Urid; *U.* Mung; *A.* Matimah; *O.* Kalamug; *P.* Muji, Mung; *G.* Lilamag; *Bom.* Mung; *Mar.* Mug; *T.* Patchaipayara; *Te.* Patchapessara; *Bur.* Pai.

Phaseolus radiatus L.
S. Masha; *B.* Mashkalai; *H.* Thikiri, Urid; *U.* Mash; *G.* Arad; *Mar.* Maga, Udid; *M.* Cherupoyara; *T.* Patchaippayarai; *Te.* Patchapesalu; *C.* Uddu; *Sin.* Ulundumae.

Phaseolus roxburghii L.
B. Mashkalai.

Phoenix dactylifera L.
E. Arabian Date palm; *S.* Pindukharjura; *B.* Khejur; *H.* Khaji, Khajur; *U.* Khurma; *P.* Khaji; *O.* Khorjjuri; *G.* & *Bom.* Khajur; *Mar.* Kharjur; *M.* Itta; *T.* Inju; *Te.* Kharjuramu, Ita; *C.* Kajura; *Sin.* Indi; *Bur.* Sunbalun.

Phoenix paludosa Roxb.
B. Hintal; *Te.* Hintalamu.

Phoenix sylvestris Roxb.
E. Datepalm; *S.* Kharjuri; *B.* & *A.* Khejur; *H.* Khajur; *O.* Khorjuro; *P* Khajur; Khaji; *G.* Kajuri; *Bom.* Khajur; *Mar.* Shindi; *M.* Inta; *T.* Inju; *Te.* Ita; *C.* Ichala; *Sin.* Indi.

Phragmites karka Trin.
E. Nodding Reed; *S.* Nala; *B.* Nalkhagra; *H.* Narkul; *O.* Noto; *G.* Nali; *Mar.* Nala; *M.* Nalam; *T.* Perunanal; *Te.* Kikkasagaddi; *C.* Hulugalagu; *Bur.* Kaing.

Phyllanthus distichus Muell-Arg.
E. Country Gooseberry; *S.* Lavali; *B.* Norh; *H.* Chalmeri; *U.* Harpharuri; *O.* Narokoli; *A.* Holpholi; *Bom.* Harparawri; *M.* Arinelli; *T.* Arunelli; *Te.* Ratsavusiriki; *C.* Aranelli; *Sin.* Ratanelli; *Bur.* Thinbawnibyu.

Phyllanthus emblica L.
E. Emblic Myrobalan; *S.* Amlika; *B.* & *A.* Amloki; *H.* Amla; *U.*

Anwala; *O.* Onola; *P.* Ambli; *G.* Amali; *Bom.* Avala; *Mar.* Anvala; *M.* Amalakam; *T.* Amalagam, Nelli; *Te.* Usirika, Amalaki; *C.* Amalaka; *Sin.* Awusadanelli; *Bur.* Hziphyu.

Phyllanthus niruri L.
S. Bahupatra; *B. & U.* Bhuiamla; *H.* Bhonyaabgli, Jaramla; *O.* Bhuiaola; *G.* Bhonyaanmati; *Bom.* Bhuiavala; *Mar.* Bhuiavali *M.* Kirganelli; *T.* Kilanelli; *Te.* Nelausirika; *C.* Kiranelligida; *Sin.* Pittawaka; *Bur.* Miziphiyu.

Phyllanthus urinaria L.
S. Shiva; *B. & H.* Hazarmani; *G.* Kharsadabonyaanmali; *Mar.* Lalmundajanvali; *M.* Chirukizhukanelli; *T.* Shivappunelli; *Te.* Ettausirika; *C.* Kempukiranelli; *Sin.* Ratpittawaka; *Bur.* Miziphiyuani.

Physalis minima L.
S. Tankari; *B.* Bontepari; *H.* Chirpoti, Tulatipati; *P.* Kaknaj; *G.* Parpoti; *Bom.* Thanmori; *Mar.* Chirboti, Dhanmori; *Te.* Kupanti; *Sin.* Hinmottu.

Physalis peruviana L.
E. Cape Gooseberry, Ground cherry; *S.* Tankasi; *B.* Tepari; *H.* Tipari, Macao; *P.* Rasbhari; *Mar.* Phopti; *T.* Siruthakkali; *Te.* Busarakaya, Buddabusara; *C.* Bondulla; *Bur.* Pongpin.

Pilea microphylla Liebm.
E. Gunpowder plant.

Pinus longifolia Roxb.
S. Dhupavrikshaka; *B.* Saralgach; *H. & P.* Chil, Chir; *O.* Sorolokatho; *G. & Mar.* Saraladeodara; *M.* Saralam; *Te.* Devadaru; *T.* Suruldevadari; *C.* Saraladevadaru.

Piper chaba Hunter
S. Chavana; *B.* Choi; *H.* Chab; *G.* Chavaka; *Mar.* Chavala; *C.* Chavya; *T.* Chaikama.

Piper nigrum L.
E. Black Pepper; *S.* Maricha, Krishna; *B.* Golmarich, Kalomarich; *H.* Gulmirich, Gulki; *O.* Golomoricha; *Bom. & G.* Kalamiri; *Mar.* Kalimirich; *M.* Maricham; *C.* Menasu; *T.* Marisam; *Te.* Marichamu; *Sin.* Miris; *Bur.* Nayukon.

Piper longum L.
E. Long Pepper; *S.* Pippali, Chanchala; *B.* Pipul; *H.* Pipli; *O.* Pippoli; *U.* Pipul; *P.* Pipal; *Bom. & G.* Pipli; *C.* Hippali, Tippali; *T.* Tippili; *Te.* Pippali; *Sin.* Tippli.

Piper betle L.
E. Betel Vine; *S.* Tambula; *B. & Bom.* Pan; *H.* Tambuli, Pan; *O.* Tambulo; *U.* Pan; *Mar.* Pan; *M.* Tambulam; *Te.* Tamalapaku; *Sin.* Balat; *Bur.* Kwan; *T.* Vethilai.

Pisonia aculeata L.
B. Baganchra; *O.* Hationkuso; *T.* Karindu, Udappu; *Te.* Konki, Pisangi; *C.* Etharumullinaballi.

Pistacia vera L.
E. Green Almond; *B.* Pesta; *H.* Pista.

Pistia stratiotes L.
E. Water Lettuce; *S.* Kumbhika; *B.* Tokapana; *H.* Jalkhumbi; *A.* Borpuni; *O.* Bolajhanji; *G.* Jalakumbhi; *Bom.* Gondala, Prashni; *Mar.* Gondala, Prasni; *M.* Koddapail; *T.* Agasatamarai; *Te.* Akasatamara; *C.* Antaragange; *Sin.* Deyaparandella.

Pisum sativum L.
E. Pea; *S.* Satila; *B.* Matar; *H.* Mattar; *A.* Motor; *P.* Khanda, Mattar; *G.* Patana; *Bom.* Vatana; *Mar.* Vatane; *M. & T.* Pattani; *Te.* Patanlu; *Sin.* Ratagoradiya; *Bur.* Pai.

Pithecolobium dulce Benth. = *Inga dulcis* Willd.
E. Manilla Tamarind; *B.* Dekani tentul; *H.* Vilayatiimli; *O.* Simakoina; *G.* Vilayatiambli, Ekadati; *Bom.* Vilayatiyamli, Chinch; *Mar.* Vilayatichinch; *T.* Kodukkappuli; *Te.* Simachinta; *Bur.* Kywetanyin.

Plumeria acutifolia Poir. = *P. rubra* L.
E. Temple tree, Pagoda tree; *S.* Devaganangalu; *B.* Goruchampa, Gulancha; *H.* Gulachin; *U.* Achin; *A.* Goalanchi; *O.* Golochi; *G.*

Radhachampo; *Bom.* Khairchampa; *Mar.* Sonchampa; *M.* Arali; *T.* Ilattalari, Perungalli; *Te.* Arhataganneru, Nuruvarahalu; *C.* Devaganagile, Ganagala; *Sin.* Alariya; *Bur.* Ta-yop-sagah.

Pogostemon plectranthoides Desf.
B. Pachouli, Juilata; *H.* Pangla, Lujra; *O.* Gondripulu; *Bom.* Pangla; *Te.* Kussurijang.

Poinciana regia Boj. = *Delonix regia* Ref.
E. Goldmohur tree; *B.* & *A.* Radhachura; *H.* Gulmohor; *O.* Radhachuda; *Bom.* Vayni; *Mar.* Sankasura; *T.* Varatti; *Te.* Sunkevaramu, Maramandaram; *C.* Sunkesari, Kattikayi.

Polianthes tuberosa L.
E. Tuberose; *S.* & *B.* Rajanigandha; *H.* Gulcheri, Gulshabha; *Bom.* Gulcheri; *P.* Gulshaboo; *T.* Nilasampangi; *Te.* Sugandharaja; *Bur.* Hnenben.

Polyalthia cerasoides Hook. f.
H. Kudumi.

Polyalthia longifolia Benth. & Hook. f.
E. Mast tree; *S.* Devadaru, Putrajiva; *B.* Debdaru; *H.* Asok, Deodar; *A.* & *O.* Debodaru; *G.* Ashopalo; *Bom.* Asoka, Asupala; *M.* Ashokam; *T.* Asogam, Asuvattai; *Te.* Asokamu, Devadaru; *C.* Putrajivi.

Polycarpea loeflingae Benth. & Hook. = *P. indicum* Merr.
S. Bhisatta; *B.* Gimashak; *H.* Sureta; *T.* Nilaisedachi; *Te.* Bommasari, Rajuma.

Polygonum barbatum L.
B. Bekhunjubaz; *P.* Narri; *Mar.* Dhaktasheral; *M.* Vellutamodelamukku; *T.* Atalari; *Te.* Kondamalle, Niruganneru; *Sin.* Ratukimbulwenna.

Polygonum hydropiper L.
E. Water Pepper; *B.* Pakurmul.

Polygonum orientale L.
E. Oriental Pepper; *B.* Panimarich, Bishkatali; *H.* Machoti; *A.* Bihlongoni; *O.* Muthisaga, Panimaricha; *P.* Narri; *M.* Mothalamooku; *T.* Atalari; *Te.* Kondamalle; *Sin.* Sudu-kumbulwenna.

Polygonum plebejum R. Br.
E. Alpine Knotweed; *U.* Anjabar; *P.* Bilauri, Maslun.

Pongamia glabra Vent. = *P. pinnata* Pierre
E. Indian Beech; *S.* Karanja, Rochana; *B.* Karanja; *H.* Karanj, Kiramal; *U.* Karanjwah; *O.* Koronjo; *P.* Karanj; *G.* Kanaji; *Bom.* Kiramal; *Mar.* Karanja; *M.* Minnari; *T.* Kanjanam, Ponga; *Te.* Kranuga; *C.* Batti; *Sin.* Magulkaranda; *Bur.* Thawen.

Pontederia vaginalis Roxb.
B. Nanku; *Te.* Nirokanob.

Populus alba L.
E. Poplar.

Porana paniculata Roxb.
E. Bridal creeper; *H.* Safedbel.

Portulaca oleracea L.
B. Chotolunia; *H.* Chhotalunia, Kulfa; *U.* Khurfah; *A.* Hanhtenga; *O.* Purunisag; *P.* Lunia, Lunak; *G.* Loni; *Bom.* Gol, Kurfah; *Mar.* Ghol; *M.* Koricchira; *T.* Karikkirai; *Te.* Pavilikura; *C.* Dudagorai; *Sin.* Gendakola; *Bur.* Mayabyit.

Portulaca quadrifida L.
S. Upadyhi; *B.* Barolunia; *H.* Loniva; *G.* Jhiniluni; *P.* Haksha; *Bom.* Barikaghola, Kota; *Mar.* Ranghol; *C.* Halibachcheli; *T.* Passelikkirai; *Te.* Kura, Pavili; *Sin.* Hingendakola.

Portulaca tuberosa Roxb.
B. Nunia; *Mar.* Jangligajar; *Te.* Boddakura; *Sin.* Uragenda.

Pothos scandens L.
B. Gajpipul; *A.* Hatilota; *O.* Gajapipali; *M.* Anapparuva; *C.* Adikabiluballi ; *Sin.* Potawel.

Pouzolzia indica Gaud.
H. Piparisari; *Te.* Eddumutteedumpa.

Premna integrifolia L.
S. Arani; *B.* Gambari; *H.* Agetha, Arni; *U.* Arani; *O.* Ogobothu; *G.* Arni; *Bom.* Arni, Marvel; *Mar.* Aran; *M.* Munna; *T.* Munnai; *Te.* Nagura, Tukkadu; *C.* Ichu; *Sin.* Karnika; *Bur.* Toungthangyee.

Prosopis spicigera L.
S. Shami; *B.* & *O.* Somi; *H.* Chhokara, Sami; *A.* Somidh; *P.* Jandi; *G.* Sami, Semru; *Bom.* Shemi, Shemri; *Mar.* Shemi; *M.* Parampu, Vanni; *T.* Jambu, Sami; *Te.* Jambi; *C.* Banni.

Prunus amygdalus L.
E. Almond tree; *S.* Badama; *B.* Belati badam; *H.* & *P.* Badam; *U.* Badamshirin; *O.* Badamo; *Mar.* & *M.* Badam; *T.* Vadumai; *Te.* Badamu; *C.* Badami.

Prunus cerasoides L. = *P. puddum* Roxb.
E. Cherry tree; *S.* Charu, Padmaka; *H.* Padam; *P.* Paddam; *G.* Padmak; *Bom.* Padmakasta; *Mar.* Padmaka.

Prunus communis Hudson
E. Plum tree; *H.* Alubukhara, Alucha; *C.* Alubokara.

Prunus domestica L.
E. Prunce tree.

Prunus persica Benth. & Hook. f.
E. Peach tree; *H.* Aru; *U.* Adud; *O.* Pishu; *P.* Aru, Arui; *C.* Pichesu.

Psidium guyava L.
E. Guava; *S.* Perala; *B.* Peyara; *H.* & *U.* Amrud; *A.* Madhuriam; *O.* Jamo; *P.* Anjirzard, Amrud; *G.* Jamrud; *Bom.* Jam, Peru; *Mar.* Jamba; *M.* Pera; *T.* Koyya; *Te.* Gova, Jama; *C.* Perala; *Sin.* Peragadi; *Bur.* Malakaben.

Psoralea corylifolia L.
S. Bakuchi, Kushthahantri; *B.* Latakasturi; *H.* & *P.* Babchi; *U.* Babechi; *O.* Bakuchi; *G.* Bavacha; *Bom.* Bawachi; *Mar.* Babachi; *T.* Karpuvarishi; *Te.* Bhavanji.

Psychotria ipecacuanha Stocks.
E. Ipecac; *H.* Kakatund; *Mar.* Kurki.

Pterocarpus marsupium Roxb.
E. Indian Kino tree; *S.* Pitasalaka; *B.* Pitsal; *H.* Bijasal; *U.* Damulakhvain; *O.* Piyasalo; *G.* Bibla; *Bom.* Asan, Bibala; *Mar.* Asana, Bibla; *M.* Venna; *T.* Asanam, Vengai; *Te.* Pedegu, Vengisa; *C.* Benga; *Sin.* Gummalu.

Pterocarpus santalinus L.
E. Red Sandal wood; *S.* Raktachandana; *B.* Lalchandan; *H.* Rukhtochandan, Undum; *G.* & *Bom.* Ratanjali; *Mar.* Raktachandan; *T.* Sandanam; *Te.* Raktachandanamu, Ettachandanamu; *C.* Raktashandana; *Sin.* Ructhandun; *Bur.* Sandaku.

Pterospermum acerifolium Willd.
S. Karnikara, Mushukunda; *B.* Kanakchampa, Moochkunda; *H.* Kathachampa, Kaniar; *A.* & *O.* Konokochompa; *Bom.* Kanakchampa, Karnikara; *T.* Vennangu; *Te.* Matsakanda; *C.* Kanakchampaka; *Bur.* Toung-pet-wun.

Pueraria tuberosa DC.
S. Ikshugandha; *B.* Shimiabatraji; *H.* & *P.* Badar, Siali; *G.* Karwinai; *Bom.* Dari, Darni; *Mar.* Badra, Pithana; *Te.* Darigummadi.

Putranjiva roxburghii Wall.
E. Child-life tree, Wild Olive; *S.* Apatyajiva; *B.* Putranjib; *H.* Jiaputa; *O.* Bholokoli; *P.* Jiyaputra; *Bom.* & *Mar.* Putajan; *M.* Pongalam; *T.* Karupalli; *Te.* Putrajivika; *C.* Amani; *Bur.* Tankyat.

Pyrus communis L.
E. Pear; *B.* Nashpati; *H.* Nukh; *P.* Batang; *T.* Perikkay; *Te.* Berikaya, Beripandu.

Pyrus malus L.
E. Apple; *S.* Savane; *B.* Apel; *H.* Seb; *C.* Sevu.

Quamoclit pinnata Boj. = *Ipomoea quamoclit* L.
E. Needle creeper; *S.* Kamalata; *B.* Tarulata, Kunjalata; *H.* Kamalata; *A.* & *O.* Kunjolota;

Bom. Ganeshvel; *Mar.* Vishnukrant; *M.* Suriyakanti; *T.* Kembumalligai; *Te.* Kasiratnamu; *C.* Kamalate; *Bur.* Mvatlaeni.

Quisqualis indica L.
E. Rangoon creeper; *B.* Brahmolata; *H.* Rangoon-ki-bel; *A.* Madhabilota; *O.* Madhumaloti; *G.* Barmasinive; *Bom.* Vilayatichambeli; *Mar.* Rangunchavel, Lalchameli; *T.* Irangunmalli; *Te.* Rangonimalle; *Bur.* Dawchmaing.

Randia dumetorum Lamk.
E. Common Emetic nut; *S.* Madana; *B.* Madan; *H.* Main; *U.* Mainphal; *A.* Gurol; *O.* Potua; *P.* Mindla; *G.* Mindhal; *Bom.* Ghela; *Mar.* Peralu, Gelaphala; *M.* Karalikkaya; *T.* Karai, Kadudam; *Te.* Madanamu, Mangara; *C.* Kare; *Sin.* Kukuruman; *Bur.* Thaminsa.

Randia uliginosa DC.
E. Grey Emetic nut; *S.* Pindalu; *B.* Piralo; *H.* Pendua, Pindar; *U.* Pindalu; *O.* Pendovoha; *G.* Gangeda; *Bom.* Pendari; *Mar.* Pendru; *M.* Punankara; *T.* Valikkarai; *Te.* Peddamranga; *C.* Kare, Pandri; *Sin.* Wadiga; *Bur.* Nyangyee.

Ranunculus sceleratus L.
E. Indian Buttercup; *B.* Palik; *H.* Bondhoniya, Shim.

Raphanus sativus L.
E. Radish; *S.* Mulaka; *B.* & *A.* Mula; *H.* Muli, Muroi; *G.* Mula, Mura; *Bom.* Mula, Muro; *Mar.* Mula, Muri; *M.* Mullangi; *T.* & *Te.* Mullangi; *C.* Bili; *Sin.* Rabu; *Bur.* Moula.

Rauwolfia serpentina Benth.
S. Chandrika; *B.* Sarpagandha, Chandra; *H.* Nai, Chotachand; *A.* Chando; *O.* Sanochado; *Bom.* Amelpodi, Chandra; *Mar.* Harki, Sarpasanda; *M.* Tulunni; *T.* Sovannamilbori; *Te.* Dumparasana; *C.* Chandrike; *Sin.* Ratekaweriya; *Bur.* Bongamaiza.

Ravenala madagascariensis Sonn.
E. Traveller's tree; *B.* Panthapadap.

Rheum emodi Wall.
E. Rhubarb; *S.* Revatchini; *B.* Revanchini; *H.* Dolu; *U.* Rewanchini; *G.* Gamnirevanchini; *P.* Atsu, Rewandchini; *Bom.* Ladakirevandachini; *Mar.* Revachini; *T.* Nattirevalchini; *Te.* Natturevalchini; *C.* Natrivalchini.

Rhinacanthus communis Nees
B. Juipana; *H* & *U.* Palakjuhi; *Bom.* Nagamalli; *Mar.* Gajakarni; *T.* Kaligai; *Te.* Nagamalle; *C.* Nagamallige; *Sin.* Anilta; *Bur.* Anitia.

Rhizophora conjugata L.
B. Khamo, Bora.

Rhizophora mucronata Lamk.
E. Mangrove; *B.* Kamo, Bhara; *O.* Rohi, Rai; *Bom.* Kandel, Hariya; *Mar.* & *T.* Kandal; *M.* Kantal; *Te.* Ponna; *C.* Kandale.

Rhus succedanea L.
E. Crab's claw; *B.* Kakrasringi; *H.* Kakrasing; *P.* Arkhol, Titri; *T.* Karkhadagachingi; *Te.* Karkkarasringi; *C.* Karkatakashringi.

Ricinus communis L.
E. Castoroil plant; *S.* Eranda; *B.* Rehri; *H.* Arand, Erend; *U.* Erenda; *A.* Eri-gach; *O.* Erondo; *P.* Arind; *G.* Diveli, Tirki; *Bom.* Erendi; *Mar.* Erandi; *M.* Amandam; *T.* Amanakku; *Te.* Amudamu; *C.* Avudalu, Haralu; *Sin.* Eudaru; *Bur.* Kyeksu.

Rivea hypocrateriformis Choisy
B. Kalmilata.

Rosa centifolia L.
E. Cabbage Rose; *S.* Vrittapuspa; *B.* Golap; *H.* & *U.* Gulab; *O.* Golabo; *P.* Gulisurkh, Gulab; *Mar.* Gulapha; *T.* Irosa, Gula; *Te.* Roja; *C.* Gulabi; *Bur.* Nhin-subin, Hninsi.

Rosa damascena Mill.
E. Bussora Rose; *S.* Shatadali; *H.* Gulab, Sudburg; *U.* Gulab; *O.* Bosora golabo; *Bom.* Sudburg; *M.* Penimirpushpam; *T.* Irosa; *Te.* Gulabi; *C.* Panniru, Tarana.

Rubia tinctorum L.
E. Indian Madder; *S.* & *B.* Manjistha; *H.* & *P.* Manjit; *A.* Majothi; *Bom.* Madar; *Mar.* & *C.* Manjeshta; *M.* Manjetti; *T.* Manjitti, Shevelli; *Te.* Tamravalli.

Rubus hexagynus Roxb.
E. Bramble; *B.* Hirachura.

Ruellia prostrata Lamk.
G. Kalighavani; *M.* Upudali; *Sin.* Nilparuk.

Ruellia tuberosa L. = *Dipterocanthus tuberosus* Nees
B. Chotpotey.

Rumex maritima L.
B. Bonpalang; *H.* Julpalam; *U.* Bijaband; *P.* Junglipalak.

Rumex vesicarius L.
E. Dock, Sorrel; *S.* Shatavedhi; *B.* Takpalang; *H.* Khattapalak, Ambori; *U.* & *A.* Chukasag; *O.* Palanga; *P.* Kattamitha, Saluni; *Bom.* Chuka; *T.* Shakkankirai; *Te.* Chukkakura; *Sin.* Suri; *Bur.* Kalakhenboun.

Rungia parviflora Nees
S. & *H.* Pindi; *G.* Mothokadsalio; *T.* Tavashumurungi, Punakapundu; *Te.* Pindikunda.

Ruta graveolens L.
E. Common Rue; *S.* Sadapaha; *B.* Ermul; *H.* Satari; *U.* Sudah; *O.* Maruya; *G.* & *Mar.* Satapa; *Bom.* Satap; *T.* Arvada; *Te.* Aruda, Sadapa; *C.* Sadabu; *Sin.* Aruda.

Saccharum munja Roxb.
S. Munja; *B.* Sar; *H.* Munja, Sarkanda; *P.* Kharkara; *Te.* Gundra, Ponika.

Saccharum officinarum L.
E. Sugarcane; *S.* Ikshu; *B.* Akh; *H.* Ganna, Ponda; *U.* Gana; *O.* Aku; *P.* Kamand, Ikh; *G.* & *Bom.* Serdi; *Mar.* Kabbo, Us; *M.* Ikshu; *T.* Karumbu, Ikku; *Te.* Cheraku, Ikshupu; *C.* Ikshu; *Sin.* Uk; *Bur.* Keyan.

Saccharum spontaneum L.
E. Thatch Grass; *S.* Kasha; *B.* Khagra. Kash; *H.* Kagara, Kans; *O.* Kaso; *P.* Kans; *G.* Kansado; *Mar.* Kagara; *M.* Nonnana; *T.* Eruvai, Nanal; *Te.* Billugaddi, Koregadi; *C.* Darbhe; *Bur.* Thetkiakyn.

Sagittaria sagittifolia L.
E. Arrowhead; *B.* Chotokut.

Salix tetrasperma Roxb.
E. Willow; *B.* Panijoma; *H.* Baishi; *A.* Bhi; *O.* Panijamo; *P.* Bakshel; *Bom.* Bacha, Baishi; *Mar.* Bitasa; *M.* Nirunji; *T.* Niruvanji; *Te.* Etipala; *C.* Bayise; *Bur.* Momaka.

Salsola kali L.
E. Saltwort; *H.* Shora; *P.* Sajjibuti.

Salvia plebeja R. Br.
E. Sage; *B.* Bhuitulsi; *P.* Sathi; *Bom.* Kammarkas.

Santalum album L.
E. Sandalwood tree; *S.* Chandana; *B.* & *A.* Chandan; *H.* Sufed chandan; *O.* Chondono; *P.* Chandan; *G.* Suket; *Bom.* Chandan, Sandal; *Mar.* Chandan; *M.* Chandanam; *T.* Sandanam; *Te.* Chandanamu; *C.* Chandala; *Sin.* Rathiri; *Bur.* Santaku.

Sapindus mukorossi Gaertn.
E. Soapnut tree; *S.* Aristha; *B.* Ritha; *H.* & *P.* Dodan; *A.* Haithaguti; *O.* Ita; *Bom.* Kannar.

Sapindus trifoliatus L. = *S. emarginatus* Wall.
E. Soapnut tree; *S.* Aristha, Phenila; *B.* Baroritha; *H.* & *U.* Ritha; *O.* Rettia; *G.* Aritha; *Bom.* Rhita; *Mar.* Ritha; *M.* Arishtam; *T.* Ponnargottai; *Te.* Kukudu, Phenilamu; *C.* Arishta; *Sin.* Antavala; *Bur.* Meav-mesuekhati.

Sapium sebiferum Roxb.
E. Chinese Tallow tree; *S.* Agaru; *B.* Momchina; *H.* Lendwa; *O.* Ronajita; *Bom.* Pipalyank; *M.* Bengieri; *Te.* Badike.

Saponaria vaccaria L.
E. Soapwort, Cow herb; *B.* Sabuni; *H.* Musna.

Saraca indica L.
E. Asoka tree; *S.* Vanjula; *B.* Asoke; *H. & P.* Asok; *O.* Osoko; *G.* Ashopatava; *Bom.* Ashok; *Mar.* Ashoka, Jasundi; *M.* Hemapushpam; *T.* Asogam; *Te.* Asokamu; *C.* Ashoka; *Sin.* Diyaratmal; *Bur.* Thawka.

Sarcolobus globosus Wall.
B. Badlilata.

Sarcostemma brevistigma Wight
S. Somavalli; *B. & H.* Somlata; *O.* Somolota; *G.* Somvel; *Bom.* Soma; *Mar.* Somyel; *M. & T.* Somam; *Te.* Somalata; *C.* Somaballi; *Sin.* Muwakiriya.

Saussurea lappa Clarke
E. Costus; *S.* Kushtha; *B.* Kur; *H.* Kust; *U.* Kut; *G.* Kut, Upaleta; *Bom.* Ouplate; *M.* Seppudy; *T.* Kostum; *Te.* Kustam; *Sin.* Godamahanel.

Schleichera trijuga Willd. = *S. oleosa* Oken.
E. Ceylon Oak; *S.* Koshamra; *H.* Gausam, Kosum; *O.* Kusumo; *P.* Jamoa; *G.* Kossamc; *Bom.* Kosam; *Mar.* Kosimb; *M.* Puvam; *T.* Konji, Puvam; *Te.* Paparti, Pullakaya; *C.* Kakuta; *Sin.* Kong; *Bur.* Kyet-mouk.

Scindapsus officinalis Schott
S. & U. Gajapippali; *B.* Gajpipul; *H.* Baripipli, Gajapipli; *O.* Gojopippoli; *G.* Mottoper; *Mar.* Thorapimpli; *M.* Attittippali; *T.* Anaittippili; *Te.* Enugatippali; *C.* Gajahippali.

Scirpus articulatus L.
B. Patpati.

Scirpus grossus L. f.
S. Kaseruka; *B.* Kesur; *H.* Kasuru; *U.* Kaseru; *P.* Kaseru, Dila; *Bom.* Kachera; *Mar.* Kasara; *Te.* Gundatengagaddi.

Scirpus littoralis Schrad.
E. Clubrush.

Scoparia dulcis L.
E. Sweet Broom weed; *B.* Bondhoney.

Semecarpus anacardium L.
E. Marking nut tree; *S.* Bhallataka; *B.* Bhela; *H.* Bhilawa; *U.* Bhitanvana; *O.* Bhollia; *G.* Bhilamu; *Bom.* Bhiba; *Mar.* Bibwa; *M.* Chera; *T.* Serangottai; *Te.* Bhallataki, Jidi; *C.* Bhallataka; *Sin.* Kiribadulla; *Bur.* Claybeng.

Sesamum indicum DC.
E. Sesame, Gingelly; *S.* Tila; Jatila; *B. & A.* Til; *H.* Gingli; *U. & P.* Til; *O.* Rasa; *G.* Mithutel; *Bom.* Ashadital, Bariktil; *Mar.* Tila; *M.* Chitelu; *T.* Ellu; *Te.* Nuvvu; *C.* Yallu; *Sin.* Talla; *Bur.* Hnan.

Sesbania grandiflora Pers.
E. Swamp tree, Sesban; *S.* Agasti, Vaka; *B. & A.* Bakphul; *H.* Agasti; *U.* Agast; *O.* Buko, Ogosti; *G.* Agathio; *Bom.* Agasta; *Mar.* Agathi; *M.* Akathi; *T.* Agatti; *Te.* Avise; *C.* Agase; *Sin.* Katuru murunga; *Bur.* Pankpan.

Seseli indicum W. & A.
S. Vanayamani; *B.* Bonjowan; *Mar.* Kiriminjiajwan.

Setaria glauca Beauv.
S. Italian Millet; *S.* Kanguni; *B.* Kakni, Kauni; *H.* Chena, Kakni; *O.* Tangun; *P.* Kangni; *G.* Karang; *Bom.* Kangi; *Mar.* Kangu; *M.* Navana, Tauna; *T.* Tennai; *Te.* Koralu; *C.* Naoni; *Sin.* Tanahal; *Bur.* Puki.

Shorea robusta Gaertn.
E. Sal tree; *S.* Ashvakarna, Sala; *B.* Shal; *H. & P.* Sal; *U.* Ral; *O.* Salo; *P.* Seral, Sal; *G.* Ral; *Bom.* Sal; *Mar.* Guggilu, Rala; *M.* Maramaran; *T.* Shalam; *Te.* Gugal, Saluva; *C.* Guggala; *Sin.* Dammala; *Bur.* Enkhyen.

Sida acuta Burm.
S. Bala; *B.* Kureta; *H.* Kareta, Kharenti; *O.* Siobola; *G. & Bom.* Bala, Janglimenthi; *Mar.* Chikana; *M.* Malatanni; *T.* Malaidangi; *Te.* Nelabenda; *C.* Vishakaddi; *Sin.* Gasbevila; *Bur.* Katsaynai.

Sida cordifolia L.
S. Svetbarila, Batyalaka; *B.* Berela; *H.* Barial; *A.* Bariala; *O.* Badi-

ananta; *P.* Kharent; *G.* Kharati; *Bom. & Mar.* Chikana; *M.* Kutturam; *T.* Nilatulli; *Te* Chiruvenda; *C.* Hettutti; *Sin.* Walbevila.

Sida rhombifolia L.
S. Lalbarila, Atibala; *B* Lalberela; *H.* Bariara; *O.* Nalobadianala; *G.* Baladana; *Mar.* Sadeda; *M.* Totti, Anakkuruntotti; *T.* Anaikurundotti; *Te.* Atibala; *C.* Bennagaragu; *Sin.* Kotikanbevila.

Siegesbeckia orientalis L.
H. Katampam.

Smilax macrophylla Roxb. = *S. zeylanica* L.
E. Indian Sarsaparilla; *B.* Kumarilata, Kumarika; *H.* Chobchini; *A.* Hastikarnalota; *O.* Kumbhatua; *P.* Ushba; *Mar.* Guti, Gutwel; *M.* Kaltamara; *T.* Ayadi; *Te.* Kondatamara; *Sin.* Kabarasa; *Bur.* Kuku.

Smithia sensitiva Ait.
B. Nalakashina; *H.* Odabirni.

Solanum ferox L.
S. Sitakanta; *B.* Rambegun; *O.* Ramobaigono; *M.* Anachchunta; *T.* Anaichundai; *Te.* Mulaka; *C.* Biligulla; *Sin.* Mallakattu; *Bur.* Sinkayan.

Solanum indicum L.
S. Kantakini; *B.* Byakur; *H.* Barhanta; *U.* Janglibringan; *A.* Tidbaghuri; *O.* Bonobryhoti; *P.* Kandyari; *G.* Motaringni; *Bom.* Motiringi, Ringani; *Mar.* Ranrigni; *M.* Cheruchunta; *T.* Karimulli; *Te.* Nellamulaka; *C.* Badane, Gulla; *Sin.* Tibbatu.

Solanum melongena L.
E. Brinjal, Egg plant; *S.* Bartaku, Brihati; *B.* Begun; *H.* Baigan; *U.* Baingan; *A.* Bengani; *O.* Baigonia; *P.* Bengan; *G.* Raigana, Ringni; *Bom.* Baigana, Venge; *Mar.* Vangi; *M.* Kattiri; *T.* Kattari, Vangam; *Te.* Hingudi, Vanga; *C.* Bhantaki; *Sin.* Wambatu; *Bur.* Ka-yan.

Solanum nigrum L.
E. Common Nightshade; *S.* Kakamachi, Jaghenephala; *B.* Kakmachi; *H.* Bhatkoi, Makoi; *U.* Makoya; *A.* Pichkati; *O.* Nannunia; *P.* Kachmach, Mako; *G.* Piludi; *Bom.* Kamuni, Mako; *Mar.* Ghati, Kakonachi; *M.* Mulagutha-kkali; *T.* Manattakkali; *Te.* Kakamachi, Kamanchi; *C.* Kanchi, Ganike; *Sin.* Kalukanweriya.

Solanum torvum Swartz
B. Titabegun; *A.* Hathibhekuri; *M.* Kattuchunta; *T.* Sundai, Kottukkattari; *Te.* Kondavusta; *C.* Sonde; *Bur.* Kayangyin.

Solanum verbascifolium L.
E. Potato tree; *S.* Vidari; *B.* Arasa, Urusa; *U.* Ola; *P.* Kalamewa; *Mar.* Kutri; *M.* Erichunta; *T.* Anaichundai; *Te.* Budama; *C.* Kadusonde; *Sin.* Hekarilla.

Solanum xanthocarpum Schrad.
S. Kantakari; *B.* Kantikari; *H.* Ringni, Kanteli; *U.* Katilla; *O.* Kontna; *P.* Katela; *G.* Bodiringni; *Bom.* Bhuringni; *Mar.* Bhuiringani; *M.* Kantankattiri; *T.* Kandangattari; *Te.* Nelavkudu; *C.* Kantakari; *Sin.* Ellabattu.

Sonchus arvensis L.
E. Sow Thistle; *B.* Bonpalang; *H.* Sadhi; *U.* Sahadevi; *P.* Bhangra; *Te.* Nallatapata.

Spatholobus roxburghii Benth.
H. Maula.

Spermacoce hispida L. = *Borreria hispida* K. Schum.
S. & H. Madanaghanti; *Bom.* Dhoti, Ghantachibaji; *T.* Nattaichuri; *Te.* Madana, Modina.

Sphaeranthus indicus L.
S. Mundirika; *B.* Chagalnadi, Gorakhamundi; *H.* Mundi, Gorakmundi; *U.* Mundi; *P.* Gurukmundi; *G. & Mar.* Gorakhamundi; *Bom.* Gorakhmundi; *M.* Attakkamanni; *T.* Kottakkarandai; *Te.* Bondatarapu; *C.* Karande; *Sin.* Mudumahana.

Spilanthes acmella Merr.
B. Marhatitiga; *H.* Akarkaru; *A.* Pirazha; *P.* Akarkarha, Pokormul; *Bom.* Akarkara; *Te.* Maratitige, Maratimogga; *Sin.* Akmalla; *Bur.* Henkala.

Spinacea oleracea L.
E. Garden Spinach; *S.* Chhurika; *B.* Palang; *H.* Chirvapalak, Pinnis; *U.* Palak; *P.* Isfanak; *Bom.* Isfanaj, Palang; *T.* Vasaiyilaikkirai; *Te.* Dumpabachchali.

Spinifex squarrosus L.
E. Seashore Grass; *M.* Edimula; *T.* Iravananbul; *Te.* Rananasuru-nimisalu; *Sin.* Maharawanare-quala.

Spondias dulcis Willd.
E. Hogplum; *B.* Amrah; *H.* Amarat.

Spondias mangifera Willd. = *S. pinnata* Kurz.
E. Indian Hogplum; *S.* Amrataka; *B.* Desiamrah; *H.* Ambara; *A.* Amara; *O.* Ambula; *P.* Bahamb, Ambara; *Bom.* Amra, Jangliam, *Mar.* Ambada, Ranamba; *M.* Ampalam; *T.* Ambalam, Marima; *Te.* Ambalamu, Kondamamidi; *C.* Amate, Pundi; *Sin.* Ambarella; *Bur.* Kywae.

Stachytarpheta indica Vahl.
E. Aronis' Rod; *H.* Kariyuttarani; *M.* Katapunuttu; *T.* Simainai-virunji; *Sin.* Balanakutta.

Stellaria media L.
E. Chickweed, Starwort.

Stephegyne parvifolia Korth. = *Mitragyne parvifolia* Korth.
B. Kelikadam; *H.* Kaddam; Kangi; *P.* Kalam, Keim; *Bom.* Kadamb, Kangi; *Mar.* Kadamb, Karamb; *M.* Vimpu; *T.* Kadam-bai; *Te.* Pulakadimi; *C.* Kadambe; *Sin.* Helembe; *Bur.* Hteinthay.

Sterculia alata Roxb. = *Pterygota alata* R. Br.
E. Buddha's Coconut; *B.* Buddha-narikel; *A.* Tula; *M.* Anattonti; *T.* Anaittondi; *Bur.* Letkope.

Sterculia foetida L.
B. & *H.* Janglibadam; *A.* Banbadam; *O.* Jangali badam; *Bom.* Pun; *Mar.* Goldaru, Jangli-badam; *M.* Pinari; *T.* Kavali, Arali; *Te.* Guttapubadamu; *C.* Bhatala; *Sin.* Kaditeni; *Bur.* Letkok.

Stereospermum chelonoides Clarke.
S. Patoli; *B.* Atkapali; *H.* Padri, Parral; *A.* Parolli; *O.* Patoli; *G.* Padeli; *Bom.* & *Mar.* Kirsel, Padal; *M.* Patiri; *T.* Padali, Padiri; *Te.* Kaligottu, Tagada; *C.* Hadari, Kaludi; *Sin.* Elapatol; *Bur.* Thakh-wotthpo.

Stereospermum suaveolens DC.
S. Ambuvasani, *B.* Parul; *H.* Paral; *O.* Poridi; *Bom.* Paddal, Paral; *Mar.* Kalagori, Parul; *M.* Patiri; *T.* Ambu, Padiri; *Te.* Ambuvasini, Patali; *C.* Hadari; *Bur.* Kywemagyolein.

Streblus asper Lour.
E. Siamese Rough bush; *S.* Bhutavriksha; *B.* Shaorah; *H.* Siora, Sahora; *O.* Sahada; *P.* Jindi; *Bom.* Karvati; *Mar.* Kharota; *M.* Paruva; *T.* Parayan; *Te.* Barinika, Paki; *C.* Mitli, Punje; *Sin.* Getanetul.

Striga densiflora Benth.
S. Kurandika; *G.* Agiyo; *Mar.* Laghukurandika.

Strobilanthes auriculatus Nees
Bom. Kara, Karvi; *T.* Kurinji.

Swertia chirata Ham.
S. Bhunimba, Chiratika; *B* Chireta; *H.* Charayatha; *U.* Chiarayata; *G.* Chirayata; *Bom.* Chiraita, Kiraita; *Mar.* Chirayita; *M.* Nilaveppu; *T.* & *Te.* Nilavembu; *Bur.* Sekhagi.

Swietenia mahagoni L.
E. Mahogany tree; *B.* Mehagoni; *H.* Abnus.

Tabernaemontana coronaria Wild. = *Ervatamia divaricata* Burhill
E. Wax flower; *S.* Nandibriksha, Tagara; *B.* Tagar; *H.* Chandni, Taggar; *A.* Kothonaphul; *O.* Togoro; *G.* Sagar, Tagar; *Bom.* Tagar; *Mar.* Ananta, Tagar; *M.* Takaram; *T.* Nandiyavarttam; *Te.* Nandivardhanamu; *C.* Kottuhale; *Bur.* Zàlat.

Tagetes patula L.
E. Marigold; *B.* & *H.* Ganda; *U.* Genda; *A.* Narjiphul; *O.* Gendu; *G.* Guljharo; *Bom.*

Makhmal, Guljari; *Mar.* Makhamala; *M.* Rojiachaphul; *Te.* Banti.

Tamarindus indica L.
E. Tamarind tree; *S.* Tintiri; *B.* Tentul; *H. & P.* Imli; *A.* Teteli; *O.* Tentuli; *G.* Ambli, Amli; *Bom.* Amli, Chintz; *Mar.* Ambali; Chinch; *M.* Amlam; *T.* Ambilam, Puli; *Te.* Amlika, Chinta; *C.* Amla, Huli; *Sin.* Siyambula; *Bur.* Magyi.

Taxus baccata L.
E. Yew; *P.* Barmi, Tung.

Tecoma stans Juss.
T. Sonnapatti; *Te.* Pachagotla; *C.* Koranckelar.

Tectona grandis L.f.
E. Teak; *S.* Sakha; *B.* Shegun; *H. & P.* Sagun, Sagwan; *U.* Sagun; *A.* Chingjagu; *O.* Saguan; *G.* Saga; *Bom.* Sagwan, Tegu; *Mar.* Saga, Sagvan; *M.* Tekka; *T.* Tekku; *Te.* Teku; *C.* Saguvani, Tega; *Sin.* Tekka; *Bur.* Kywon.

Tephrosia purpurea Pers.
E. Wild Indigo, Hoary Pea; *S.* Sharapunkha, Plihari; *B. & A.* Bonnil; *H.* Sarphoka; *U.* Sarabhika; *O.* Pokha; *P.* Bansa, Sarphonka; *G.* Sarpankho; *Bom.* Janglikulthi, Sarpunkha; *Mar.* Sirapakha; *M.* Kolinnil; *T.* Kalunibi; *Te.* Vempan; *Sin.* Pila.

Teramnus labialis Spreng.
S. Mashaparnia; *B.* Mashani; *H.* Mashoni; *G.* Valiyovelo.

Terminalia arjuna W. & A.
E. White Murdah; *S.* Arjuna; *B. & H.* Arjun; *A.* Orjun; *O.* Orjuno; *P.* Arjan, Jumla; *G.* Arjunsadada, Sadado; *Bom.* Arjun, Jamla; *Mar.* Arjuna; *M.* Marutu; *T.* Marudu; *Te.* Maddi; *C.* Arjuna; *Sin.* Kumbuk; *Bur.* Toukhyan.

Terminalia belerica Roxb.
E Belleric Myrobalan; *S.* Beheduka, Vibhitaka; *B.* Bahera; *H.* Bhaira; *U.* Behera; *A.* Bauri; *O.* Bahada; *P.* Bayrah; *G.* Bahedo; *Bom.* Beheda; *Mar.* Bahera; *M.* Tanni; *T.* Tanri, Vibidagam; *Te.* Tandra, Vibhitakamu; *C.* Vibhita, Tari; *Sin.* Bulu; *Bur.* Thitsein.

Terminalia catappa L.
E. Indian Almond; *S.* Desabadama, Ingudi; *B.* Deshibadam; *H.* Badami, Janglibadam; *A.* Badamgoch; *O.* Badamo; *C.* Badamalili; *Bom.* Badam; *Mar.* Janglibadam, Natbadam; *M.* Nattubadam; *T.* Amandi, Nattuvadumia; *Te.* Ingudi, Natubadamu; *C.* Badami; *Sin.* Kotamba.

Terminalia chebula Retz.
E. Black Myrobalan; *S.* Himaja, Haritaki; *B.* Haritaki; *H.* Harra; *U.* Haejarad; *O.* Horitoki; *P.* Harrar; *G.* Hirdo; *Bom.* Harada; *Mar.* Hirda; *M.* Putanam; *T.* Amagola, Kadukkay; *Te.* Haritaki, Karaka; *C.* Harade; *Sin.* Aralu; *Bur.* Pungah.

Terminalia tomentosa W. & A.
E. Black Murdah; *S.* Sajada; *B.* Asan; *H.* Asna; *A.* Amari; *O.* Sahajo; *P.* Aisan; *G.* Sadada; *Bom.* Asna, Sadri; *Mar.* Madat, Sadada; *M.* Marutu; *T.* Marudam; *Te.* Maddi; *C.* Matti; *Sin.* Kumuk; *Bur.* Toukhyan.

Thalictrum javanicum Bl.
E. Meadow Rue; *B.* Gurbiani; *H.* Mamira; *P.* Chireta.

Theobroma cacao L.
E. Cocoa tree.

Thespesia populnea Corr. = *Hibiscus populneus* L.
E. Portia tree, Tulip tree; *S.* Parisa, Gardabhanda; *B.* Pareshpipul; *H.* Paraspipal, Bonkapas; *O.* Habeli; *P* Bendi; *G. & Bom.* Bhendi, Gunjausto; *Mar.* Bendi, Paraspipar; *M.* Pupparutti; *T.* Kallal, Puvarasu; *Te.* Gangaravi; *C.* Bugari, Huvarasi.

Thevetia neriifolia Juss. = *T. peruviana* K. Schum.
E. Yellow Oleander; *S.* Karavira; *B.* Kolkeyphul, Holdeykarabi; *H. & P.* Pilakaner; *A.* Karabi; *G.* Pilokanera; *Bom. & Mar.* Pilvalakaner; *M.* Pachchaarali; *T.* Tiruvachippu; *Te.* Pachchaganeru.

Thunbergia grandiflora Roxb.
B. & H. Nil-lata.

Thymus serphyllum L.
E. Thyme.

Toddalia aculeata Pers. = *T. asiatica* Lamk.
E. Forest Pepper; *S.* Dahana; *B.* Kadatodali; *H.* Kanj; *O.* Tundopoda; *Bom.* Janglikalimirchi; *Mar.* Limri, Manger; *M.* Tutali; *T.* Kattumilagu; *Te.* Kondakasinda; *C.* Kadumenasu; *Sin.* Kudumirish; *Bur.* Kyanzah.

Tragia involucrata L.
E. Indian Nettle; *S.* Vrischikali; *B.* Bichuti; *H.* Barhanta; *A.* Chorat; *O.* Bichchuati; *Bom.* Kanchkuri, Khajkotti; *M.* Choriyanam; *T.* Kanjori; *Te.* Dulagundi, Telumani; *C.* Dulagondi; *Sin.* Welkahambiliya.

Trema orientalis Bl.
E. Charcoal tree; *S.* Jivani; *B.* Jibon; *Bom.* Gol, Khargul; *Mar.* Gol; *M.* Omi, Ratti; *T.* Munnai, Oman; *Te.* Morali, Privalu; *C.* Gorklu; *Sin.* Gedumba; *Bur.* Sapchapen.

Trewia nudiflora L.
S. Pindara; *B.* Pituli; *H.* Gamhar, Tumri; *A.* Bhelkora; *O.* Monda, Pithaliya; *Bom.* Petari, Tumri; *Mar.* Pitari; *M.* Kanji, *T.* Attarasu; *Te.* Eruponaku; *Bur.* Thitmyoke.

Trichodesma indicum R. Br.
S. Andhapuspi; *B.* Chotakulpa; *H.* Andhahuli, Chhotakulpha; *P.* Ratmandu; *G.* Undhaphuli; *T.* Kalhudaitambai; *Te.* Guvvagutti.

Trichosanthes anguina L.
E. Snake Gourd; *S.* Chichinda; *B.* Chichinga; *H.* & *U.* Chachenda; *A.* Dhundul; *O.* Chachindara; *P.* Chichinda, Pandob; *G.* Padavli; *Bom.* Padavala, Pandolu; *Mar.* Padual; *M.* Patolam; *T.* Podivilangu, Pudol; *Te.* Potla; *C.* Padavala; *Sin.* Patola; *Bur.* Pai-len-mwae.

Trichosanthes dioica Roxb.
E. Palwal; *S.* Patola; *B.* Patol; *H.* Palval, Parvar; *U.* Parawal; *A.* & *O.* Patal; *P.* Palwal; *G.* Potala; *Mar.* Karuparval; *M.* Patolam; *T.* Kombuppudalai; *Te.* Kommupotla.

Trichosanthes palmata Roxb. = *T. bracteata* Voigt.
S. Mahakala; *B.* Makal; *H.* & *U.* Indravan; *G.* Rataindravanan; *Bom.* Kaundal; *Mar.* Mukal; *M.* Kakatonti; *T.* Korattai; *Te.* Donda; *C.* Avagudehannu.

Tridax procumbens L.
B. Tridaksha.

Trigonella corniculata L.
S. Malya; *B.* Piring, Bonmethi; *H.* Mathi; *U.* Pirang; *Mar.* Tirapa.

Trigonella foenum-graecum L.
S. Methika; *B.* & *H.* Methi; *U.* Methi; *A.* Mithiguti; *P.* Methri; *G.* Methro, Methini; *M.* Venthiam; *T.* Vendayam; *Te.* Mentikura, Mentulu; *C.* Mente; *Sin.* Uluhal; *Bur.* Penantazi.

Triticum aestivum Lamk. = *T. vulgare* Vill.
E. Wheat; *S.* Godhuma; *B.* Gom; *H.* & *P.* Gehun, Giun; *A.* Ghennu; *O.* Gohoma; *G.* Gawn, Govum; *Bom.* Gahu, Gohum; *Mar.* Gahum; *M.* Gendum; *T.* Godumai; *Te.* Godumulu; *C.* Godhi; *Sin.* Tiringu; *Bur.* Giyonsaba.

Triumfetta rhomboidea Jacq. = *T. bartramia* L.
E. Spiny Cocklebur; *S.* Jhinjharita; *B.* Bonokra; *H.* Chikti; *O.* Bojoromuli, Jotojoti; *G.* Jhiapato; *Bom.* Nichardi; *Mar.* Jhinjudi; *T.* Ottuppulu; *Te.* Tutturubenda; *Sin.* Epala.

Tylophora asthmatica W. & A. = *T. indica* Merr.
B. Antomul; *H.* Antamul; *O.* Mendi, Mulini; *Bom.* Anthamul, Pitmari; *Mar.* Pitakari; *M.* Vallippala; *T.* Kodagam, Kagittam; *Te.* Kakapala; *C.* Nepala; *Sin.* Binnuga.

Typha angustata Chaub. & Bory
Te. Jambu, Jammu.

Typha elephantina Roxb.
E. Bulrush; *S.* Eraka, Shari; *B.* Hogla; *H.* Paer; *P.* Bon; *G.*

Ghabajarin; *Bom.* Ramban; *Mar.* Eraka, Rambana; *T.* Chambu; *Te.* Kandra; *C.* Apu, Jambuhullu.

Typhonium trilobatum Schott.
B. Ghetkachu, Ghetkol, Kharkon; *H.* Khain; *A.* Samakachu; *M.* Chena; *T.* Karkarunaikkilhangu; *Te.* Kandagadde; *Sin.* Pankala.

Uraria picta Desv.
B. Sankarjata; *H.* Prishniparri.

Urena lobata L.
S. Vanabhenda; *B.* Bonokra; *H.* Bachata; *A.* Bonagara; *O.* Jotjotia; *Mar.* Vanavenda, Rantupkada; *M.* Uram; *T.* Ottatti; *Te.* Peddabenda; *C.* Otte; *Sin.* Vabtaepala; *Bur.* Katsenai.

Urena sinuata L.
B. Kunjia; *H.* Lotloti; *Mar.* Ramkopasi; *M.* Uram; *T.* Ottatti; *Te.* Nallabenda; *Sin.* Hin-appele.

Urtica urens L.
E. Common Stinging nettle; *B.* Bichuti; *H.* Bichubuti.

Utricularia stellaris L.
E. Bladderwort; *B.* Jhanji; *M.* Mullanpayal, Kalakkannan; *Sin.* Nilmonaressa.

Uvaria macrophylla Roxb. = *Fissistigma macrophylla* Merr.
B. Baghranga.

Vallisneria spiralis L.
E. Tape grass, Eel grass; *B.* Patajhanji, Baicha; *H.* Sawala, Syala; *G.* Jalasarpolian; *T.* Velampasi; *Te.* Punatsu.

Vanda roxburghii R. Br.
E. Common Orchid; *S.* Vandaka, Nakuli; *B.* Rasna; *H.* Banda, Nai; *A.* Koponphul; *U.* Banda; *O.* Madanga; *G.* Rasno; *Bom. & Mar.* Rasna; *M.* Maravazha; *Te.* Mardaru; *C.* Bandanike.

Vangueria spinosa Roxb. = *Meyna laxiflora* Robyns.
S. Pindu; *B.* Moyna; *H.* Moina; *A.* Kotkora, Moyentenga; *O.* Monono; *Bom.* Alu, Atu; *Mar.* Halawni, Huloo; *T.* Manakkarai; *Te.* Segagadda, Veliki; *C.* Gundkare. Mullakare; *Bur.* Hsaymakyi.

Vanilla planifolia Andr.
E. Vanilla; *T.* Vanikkodo.

Vatica scaphula Dyer.
B. Boilshura.

Ventilago maderaspatana Gaertn.
S. Raktoballi; *B.* Raktopit; *H.* Pitti; *O.* Ruktupita; *G.* Ragatarohado; *Bom.* Kanvel; *T.* Vembadam; *Te.* Ettashirattalativva.

Verbena officinalis L.
E. Vervain; *U.* Faristariun.

Vernonia anthelmintica Willd.
S. Somraji; *B.* Somraj; *H.* Somraj. Kali-ziri; *Mar.* Karalye; *T.* Kattushiragam; *Te.* Advijilakara.

Vernonia cinerea Less.
E. Iron weed; *S.* Sahadevi; *B.* Kukshim, Shealmotra; *H.* Sahadevi; *O.* Jhurjhuri; *G.* Sadodi; *Bom.* Motisadori; *Mar.* Sahadevi, Sadodi; *T.* Puvamkarundal, Sahadevi; *Te.* Garitikamma; *C.* Sahadevi; *Sin.* Monarakudimbiya.

Vicia faba L.
E. Broad Bean, Windsor Bean; *B.* Shim; *H.* Bakla; *T.* Vempadam.

Vigna catjang Endl.
E. Cow Pea, Asparagus Bean; *S.* Rajamasha; *B.* Barboti, Lalsha; *H.* Bora, Rausa; *A.* Noseramah; *O.* Baragada; *P.* Lobiya; *G.* Chola; *Bom.* Lobeh; *Mar.* Chhoti; *M.* Nisendi; *T.* Caramunni; *Te.* Alusandi, Bobra; *C.* Alasandi; *Sin.* Mekaral.

Vinca rosea L. = *Lochnera rosea* Reichb.
E. Periwinkle; *B.* Nayantara; *H.* Gulferinga. Sadabahar; *O.* Ainskati; *P.* Rattanjot; *Mar.* Sadaphul; *M.* Kasithumpa; *T.* Pottipu; *Te.* Billaganneru; *C.* Sadamallikai, Kempukasiganegilu; *Sin.* Sohanmal, Mini-mal; *Bur.* Thembanmahnyoban.

Viola odorota L.
E. Sweet Violet; *S.* Nilapuspa, Vanapsa; *B.* Banosa; *H.* Banafsha; *G.* Banaphsa; *Mar.* Bagabanesa.

Viola tricolor L.
E. Pansy.

Viscum album L.
E. Mistletoe; *B.* Banda; *H.* Bhangra; *A.* Roghumala; *O.* Malanga; *U.* Maizakeasli; *M.* Iththil; *T.* Ottu.

Vitex negundo L.
E. Chaste tree; *S.* Indrani, Nirgundi; *B.* Nishinda; *H.* Shamalu, Sambhalu; *O.* Begudia; *P.* Banna; *G.* Nigari; *Bom.* Katri; *Mar.* Nirgundi, Vanai; *M.* Indrani; *T.* Vellainochi, Nirkundi; *Te.* Nallavavili; *C.* Bilenekki; *Sin.* Nikka.

Vitis quadrangularis Wall. = *Cissus quadrangularis* L.
E. Large Granadilla; *S.* Vajraballi, Asthisanhari; *B.* Harjora, Harbhanga; *H.* Nallor, Kharbi; *A.* Harjora; *O.* Harbhanga; *G.* Chordari; *Bom.* Harsankar; *Mar.* Chaudhari, Kandavela; *M.* Piranla; *T.* Pirandai; *Te.* Nalleru; *Sin.* Hiressa; *Bur.* Shazanlese.

Vitis pedata Vahl = *Cayratia pedata* Gagnep.
S. & *H.* Godhapadi; *B.* Goalilata; *Mar.* Gorpadvel; *M.* Tripadi; *T.* Naralai; *Te.* Edakula; *Sin.* Mediya-wel.

Vitis setosa Wall = *Cissus setosa* Roxb.
E. Hairy Wild vine; *B.* Chotogoalilata; *H.* Harmal; *O.* Ambilidonkonio; *Mar.* Khajgotichavel; *T.* Kauri; *Te.* Pallatachali; *C.* Talavaranaballi.

Vitis trifoliata Clarke
B. Amal-lata; *H.* & *P.* Amalbel; *O.* Molobhangonai; *G.* Khat; *Bom.* Odi; *Mar.* Amlatbel; *M.* Sorivalli; *C.* Heggoli; *Te.* Kadepatige; *Sin.* Valratdiyalbau.

Vitis vinifera L.
E. Grape, Vine; *S.* Draksha; *B.* & *H.* Angur; *O.* Drakya, Onguro; *P.* Dakh, Dakki; *G.* Drakh; *Bom.* Abai; *Mar.* Draksha; *M.* Muntirika; *T.* Kottani, Draksha; *Te.* Kisumiai, Draksha; *C.* Drakshe; *Sin.* Muddrap; *Bur.* Sabyit.

Waltheria indica L.
B. & *H.* Khardudhi.

Webera campaniflora Hook. f.
B. Kankra.

Wedelia calendulacea Less.
S. Bhringaraj, *B.* Kesaraj; *H.* Bhangra; *A.* Bhimraj; *O.* Bhurangoraja; *G.* Bhangaro; *Bom.* Pivalabhangra; *Mar.* Pivalamaka; *M.* Pekayyannum; *T.* Tatalaikaintagerai; *Sin.* Ranyan, Kikirindi.

Wendlandia exserta DC.
H. Chattlai, Tilai; *M.* Puvu; *T.* Kadambaram; *Te.* Tellapukku; *C.* Koyire; *Sin.* Navanidala.

Willughbeia edulis Roxb.
B. Lata-am.

Withania somnifera Dun.
S. & *B.* Aswagandha; *H.* & *P.* Asgandh; *G.* Asoda; *Bom.* Asgund; *Mar.* Kanchuki, Askandha; *M.* Pevetti; *T.* Asuvagandi, Amukkira; *Te.* Ashvaganda; *Sin.* Amukkara.

Woodfordia floribunda Salisb. = *W. fruticosa* Kurz.
S. Dhataki; *B.* Dhatriphul, Daiphul; *H.* Dhai, Dhawi; *O.* Jatiko; *P.* Dahai, Dawi; *G.* Dhawani; *Bom.* Dhatuko; *Mar.* Dhaiti; *T.* Velakkai; *Te.* Sirinji; *C.* Are, Bela; *Sin.* Malitta; *Bur.* Pattagyi.

Wrightia coccinea Sims.
B. & *H.* Pallam.

Wrightia tomentosa Roem. & Schult.
B. Dudhi, Dudhkoraiya; *H.* Dudhi, Darauli; *A.* Atkuri; *O.* Kudelo; *P.* Dudhi; *G.* Ruchhahalodudhato; *Bom.* Daira; *Mar.* Tamdakura; *M.* Nilampala; *T.* Palsi; *Te.* Kolamukhi, Pala; *C.* Kadunagalu; *Bur.* Lettopthein.

Xanthium strumarium L.
E. Common Cocklebur; *S.* Shankapuspi; *B.* Gagra, Bichaphal; *H.* Chotadatura, Chotagoghuru; *A.* Agara; *O.* Chotagoghuru; *P.* Chirru; *G.* Gadriyun; *Bom.* & *Mar.* Shankesvara; *T.* Marlumutta; *Te.* Marulutige; *Bur.* Koukpin.

Xylia dolabiformis Benth.
S. Kanakakuli; *H.* Jambu; *O.* Boja, Kongora; *Bom.* Jamba, Surai; *Mar.* Jambha; *M.* Irimpullam; *T.* Iruvul; *Te.* Boja; *C.* Jambe.

Yucca gloriosa L.
E. Adam's needle.

Zanthoxylon trifoliatum L. = *Acanthopanax trifoliatum* Merr.
E. Prickly Ash; *S.* Laghubalkala; *B.* Bazinali; *A.* Brojonali; *G.* Gejabala; *Bom.* Chirphal, Triphal; *Mar.* Chiphal; *M.* Kattumurikku; *T.* Iratchai; *Te.* Rachamam; *Sin.* Kattukina.

Zea mays L.
E. Maize, Indian corn; *S.* Makaya; *B.* Bhutta; *H.* Bhutta, Makka; *U.* Makai; *A.* Makaijoha; *O.* Maka; *P.* Makki; *G.* Makkari; *Bom.* Buta, Makai; *Mar.* Maka; *M.* Cholam; *T.* Makksholam; *Te.* Mokkajana; *C.* Mekkejola; *Sin.* Bada-irangu; *Bur.* Py-on-eg-boon bin.

Zehneria umbellata Thw.
B. Rakhalsasha, Kudari; *H.* Tarali; *Bom.* Gometta; *Te.* Tiddanda.

Zeuxine sulcata Lindl.
B. Shethuli.

Zingiber officinale Roscoe
E. Ginger; *S.* Adraka, Sringavera; *B.* & *A.* Ada; *H.* Adrak; *U.* Adraka; *O.* Adroko, Oda; *G.* Adu; *Bom.* Ale, Adu; *Mar.* Ale; *M.* Inji; *T.* Inji, Sukku; *Te.* Sunthi, Allamu; *C.* Sunti, Alla; *Sin.* Inguru; *Bur.* Khyen-seing.

Zizyphus jujuba Lamk.
E. Jujube, Indian plum; *S.* Badari; *B.* Kul, Borui; *H.* Ber, Baer; *U.* Ber; *A.* Agari; *O.* Barkoli, Bodori; *P.* Ber, Beri; *G.* Ber, Bor; *Bom.* Bor; *Mar.* Baher, Bera; *M.* Badaramu; *T.* Illandai, Kulvali; *Te.* Regu; *Sin.* Mahadebara; *Bur.* Zi, Ziben.

Zizyphus oenoplia Mill.
E. Indian Buck-thorn; *S.* Srigalkoli; *B.* Shyakul; *H.* Makai, Mahkoa; *A.* Banbageri; *O.* Barokoli, Kontakoli; *Mar.* Ghainthi, Makor; *T.* Surai; *Te.* Banka; *C.* Barige, Challi; *Sin.* Uk, Erraminyavel.

Zornia diphylla Pers.
M. Nelammari.

INDEX

(Generic names of angiospermic plants only are given in Italics).

C

F

I

J

K

L

M

N

O

P

Q

R

T

U

V